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Practical Application of the Theory of Games to Complex Managerial Decisions

By Spencer A. Weart

Vice President, Barrington Associates, Inc.

Frequently, in the management of even the smallest industrial enterprise, complex decisions must be made. Such decisions require that numerous factors must be weighted, one combination of variables equated against all other possible combinations, and a final answer found by some abstruse mental solution of what is really an integral or differential equation. All of this quasi-mathematical process is lumped under the heading of "business judgment", and rarely can the manager trace back the actual steps by which he arrived at his decision in a marginal case, and seldom can he formulate the equations in mathematical terms, despite their real existence. At this point, I hasten to say that managerial decisions never can be purely mathematical, because of the impossibility of assigning exact numbers to intangibles. But, the mental torture of evaluating the factors can be reduced or eliminated, by analyzing a problem and expressing it in a form that permits a *yes* or *no* decision, instead of a *yes-but* or *no-but*.

The procedure for doing this is spelled out in a complicated mathematical manner in the *Theory of Games*. There is, however, a simple, practical method for applying this interesting theory to complex managerial problems, reducing them to ordinary terms for an easy, reliable, obvious decision.

Theory of Games

The theory of games is usually considered to have originated in the late 1920's with the mathematician, J. Von Neumann, who was the first to show that all games could be expressed in the form of a matrix, that is, a diagram or grid, in which one set of factors is arrayed vertically, another set, horizontally, and values assigned or computed for each intersection. For example:

Should I Carry an Umbrella?

Choice \ Variable	It Rains	It Does Not Rain
Carry	Do Not Get Wet	Do Not Get Wet
Do Not Carry	Get Wet	Do Not Get Wet

In only one of the four possible values is there a possibility of an unfavorable result, which may explain why few people carry umbrellas. But this is only part of the problem, for now the relative weighting of each variable must be considered—what it costs to own and carry an umbrella, and what it costs if I get wet. When mathematical values are assigned to each of the variables, we might get this, for example:

Should I Carry an Umbrella?[1]

Choice \ Variable	It Rains	It Does Not Rain
Carry	$0.50	$0.60
Do Not Carry	$1.25	0

A mathematician will tell you that this matrix figures out[2] at 25 to 2, with a game value of $0.55½, namely, out of every 27 times, on 25 of them I should carry an umbrella, and if I do, I will be $0.55½ better off each time I am right. Now, such a conclusion is really very surprising, and it would appear that the world should teem with umbrella toters. One reason it does not, is that we have not taken into account the chances of it raining while I am outside. If the weather map is such that the chances of rain are 1 to 5; and if my expectation of being outside is 1 to 10, then the odds against being caught outside in the rain are 1 to 50, and the matrix would be:

[1] For those who wonder where the values come from the following may suffice: cost of owning a $5.00 umbrella, lost after 10 times carried—$0.50; cost of carrying an umbrella when it does not rain—the above $0.50 plus $0.10 checking charge; cost of getting suit pressed—$1.25.

[2] Those interested in pursuing the mathematics further are referred to "The Compleat Strategyst" by J. D. Williams (McGraw-Hill Book Company—1954) for an elementary but sufficient explanation of how this is done. Those wishing a more complete mathematical discussion are referred to "Introduction to the Theory of Games" by J. C. C. McKinsey (McGraw-Hill Book Company—1952), which has a quite complete bibliography for those wishing to go still further.

Should I Carry an Umbrella?

Choice	Variable: It Rains	Variable: It Does Not Rain
Carry	$0.50	$0.60
Do Not Carry[1]	$0.02½	0

This time the diagram states unequivocably that I should never carry an umbrella, for whether it rains or not my loss is less if I do not have the umbrella. Since this is more nearly the average situation in real life, few people carry umbrellas in average weather.

In brief, all of the foregoing is a simple application of game theory to what is known as a *2 x 2* game, there being two choices and two variables. If there were three variables the game would be called *2 x 3*, and so on, to *2 x n*. In practice, most business decisions have only two choices, or can be reduced to only two choices—*do* or *do not*, but there are more than two, or *n* variable factors. It so happens that the *2 x n* game lends itself to a very simple graphic and arithmetical solution.[2] Where there are three or more choices, no easy solution is available without resorting to more involved mathematics, or perhaps to a lengthy process of trial and error. Occasionally this may be necessary,[3] but in business it is a rare problem that cannot be reduced to a *yes* or *no* choice, and hence a *2 x n* format.

There are, of course, marginal cases where the answer may not always appear to be the simple *yes* or *no* demanded by the *2 x n* form. The decision cannot be *yes-but*, but it could perhaps be a *yes* handled in a different manner. Should the unprofitable store be continued open or should it be closed? There is another possibility—it might be burned down for the insurance, and with the new working capital thereby gained, re-opened, that is, continued—illegal, perhaps, but nonetheless a possible choice. The answer need not always be a dense black or glaring white, for sometimes a grey answer may be wisest. However, in game theory, each grey can become another choice. If there are more than two possible choices, they can be considered sequentially, but it may be simpler to admit that the game is of a variety higher than *2 x n*.

Assume the question of where a national headquarters office should be located. Should it be in New York City, Chicago, Boston? The choices are three, and the measurable variables can be many—travel costs to plants, state income taxes, office rent, clerical personnel availability, for example. This situation should not be forced into a *2 x n* mold, but should be worked out according to the more complicated rules of *3 x n*. If there were five candidate cities, a *5 x n* diagram would be best. Care is necessary to assure that the problem is not really one of linear programming—the best distribution, for example, of a known limited resource to satisfy a known limited demand. Such problems do not belong to game theory, which is only concerned with the *if* questions—what is the effect *if* this-or-that happens.

A large field of managerial decisions to which no mathematical procedure is applicable is that of human relations. Definite numerical values cannot be assigned to the intangibles of whether or not Jones will make a good sales manager, of whether or not to let the Union have that seniority clause. Here the manager is left to his well-scratched crystal ball. But the fact that game theory does not give an answer to everything need not discourage its use where applicable.

There are innumerable business problems of the *2 x n* type, of which the following are representative:

Should a New Plant Be Built to Serve a Certain Market?

There are a number of often conflicting variables: the effect upon present plant overhead through decreased volume—the saving in freight—the reduction or increase in inventories, and in labor or material costs—the cost of newly borrowed funds. While it is not difficult to compute the net gain or loss for a given set of conditions, many contingencies must be faced: If the sales volume does not increase, as hoped? If freight rates rise? If a competitor also builds a plant in that area?

A similar problem is whether two plants should be combined, or one plant divided into two.

Should a Certain Product be Discontinued or Added?

Among others, the variables may be: the effects on competing lines, on manufacturing overhead, on sales of nearly similar Company products. Even if difficult to assign exact quantities, the values certainly will range within relatively narrow finite limits. Computations can be made to show what will happen under various possibilities.

A corollary problem would be the raising or lowering of the selling price of one item or line.

Should a Company be Purchased?

Here the variables are many indeed, for frequent unknowns enter into any calculation based upon an assumed static set of conditions. The proper and safe procedure is to set up a game theory diagram, and determine the worst that could happen: the loss of sales, the carrying of an idle plant, the necessity for increased overhead.

A related problem is whether or not a subsidiary company or plant should be sold.

All of the foregoing are essentially *yes* or *no* problems, and the decision, once made, is all too frequently irrevocable. But whereas the number of choices is only *2*, the number of variables is truly *n*—the effect on sales, on

[1] Method of applying the odds is explained later.

[2] The procedure is explained later under the caption "An Example".

[3] Games of the *3 x n* type can be solved by a 3-dimensional graph, but *4 x n* and higher types really require the solution of matrices.

competitors, on profits, on operating expenses, and so on, presents a complex of variables, each with its own importance as to weighting, each with its own influence, each contributing its mass, or its little but still not insignificant mite, to the pot which must somehow be cooked up into a decision by the manager. A practical application of game theory can bring order out of this mixture, and array the facts so that an obvious, but otherwise hidden, solution will become visible.

The Procedure

Before the basic principles of game theory can be applied, the problem must be clearly defined in terms of its variables, reducing each variable to one plain, self-contained question. For example, if a 4½-ounce size of a certain product is discontinued, what will be the effect upon *each* of: (A) sales of the retained 3-ounce size? (B) sales of the retained 6-ounce size? (C) sales of competitors 4½-ounce sizes? and (D) factory overhead? to name only several. It is not correct procedure to try to consider simultaneously even these few factors.

The proper method is use of the technique of pure research, which holds all but one of the variables constant, and then determines the effect of fluctuations in the one, and only one, variable under study at the moment. A complex problem will become at least to some degree simplified, for the limits of the individual variable are assuredly known, and usually clear. In the example 4½-ounce size problem, the worst that can happen in variable (C) is that competition will get all the previous 4½-ounce sales; the best that can happen is that they will get none of them. Once the maximum and minimum are known, a little thought will quickly lead to a logical, practical figure at some position between the limits. The point here made is that an ind. cident and isolated analysis occurs, disregarding, for example, what might happen to the 6-ounce sales.

Each variable in turn is studied in its own separate, distinct fashion, and the potential gain or loss under the strictly circumscribed set of conditions is established. Values must be in terms of comparable units, the dollar being most suitable. A few variables may be found for which no monetary or definite arithmetical value can be set. Such are few indeed, and where encountered must be left for later consideration, at which time it may be found that they are non-governing, and can be ignored.

Wherever applicable, odds can be applied before determining the final unit value of the variable. In the umbrella example, the odds of being caught outside in the rain were 1 to 50. That is, the penalty of an unfortunate choice is only $\frac{1}{50}$th of the amount first indicated, for the occurrence will happen only once in fifty times. The amount entered in the diagram is properly computed at only this fraction of the otherwise effective value.

After each variable situation has been independently evaluated, all variables are lined up side by side, as in the umbrella example, with still only two choices, but with many additional variables extending to the right. Here is where game theory really begins to apply, and hence the advisability of restricting the number of choices to two, or at most three, so as to permit a simple mathematical solution.

The final step in pure game theory is determination of the controlling variables, or computation of the correct odds and game value for the specified set of circumstances. The conclusion will be that "the odds are thus-and-so in favor of (against) making thus-and-so much profit". This is a noteworthy answer in itself, and one which many a perplexed manager might well be glad to learn. Even though his final decision might be based upon some (relatively rare) intangible not susceptible of definition in monetary terms, yet this answer would at least have eliminated all other variables, after considering them all simultaneously, each weighted in proper proportion, and giving in one answer the composite result. With this answer the customary mathematical aspects of game theory would terminate, but *the practical application is merely about to start.*

In business, human nature and our economic system being what they are, managers are usually seeking the most favorable results. In game terminology, this would be a *saddle-point* (a pure strategy or sure-fire choice) and high game value; or, if this is impossible, then the most favorable odds, and again a high game value. Where there is no sure choice, game theory terminology calls the answer a *mixed strategy.* Nature being what it is, the initial computations frequently, even usually, are disappointing, and show either or both unfavorable or too low odds, and low game value. The investment of $100,000 in an increased sales force is hardly worth-while if the chances are only 2 out of 7 that $5,000 can thereby be gained. The first computation, which was the final step in game theory, is only a sort of opening gambit.

The variables must be inspected one by one, after an unfavorable answer, to see which are responsible for the unwanted results. When found, each such variable must be searched, once again, to see if it contains within itself some element which alone caused the discouraging results. That increase in the sales force half the unfavorable expense increase was for a California branch what if no branch were opened, but the territory merely traveled? A new look with a jaundiced eye may pin-point the part of the program which is causing the bad odds or the low game value out with it! The part must be sacrificed to retain at least part of the merits of the whole. Conversely, an increase in some expense may tip the balance favorably.

After the search, the isolation of the cause, the re-evaluation of variables, comes the new computation of odds and game value, or if lucky, the finding of the one sure, correct choice. If unlucky, and results are still not favorable enough, then the process must be repeated, and if necessary, repeated again. Finally, the time will come when all possible changes have been exhausted, and the computed results must be accepted. If favorable enough, manage-

ment's choice is simple—proceed with the plan. If not favorable, the plan must be abandoned, and lucky the manager who otherwise might have proceeded on pure hunches. A complex problem, with its seemingly infinite variations, has been reduced to simple odds for a given stake, asking the manager only whether the game, at such odds, is worth the gamble. The manager then can hazard the risk in the knowledge that, if wrong this time, in the long run he must win.

It is important that the manager know the principles of game theory and that he help in defining and setting up the problem, but it is not essential that he make the computations himself. In the case of games of *3 x n* and higher order the average executive has neither the mathematical inclination nor time to work out the solution. Just as the computation of values for each variable and choice is left to engineers and accountants, so is the solution of the diagram, once set up, best left to these assistants or to the mathematician. There is no objection to the manager figuring the answer himself, but it is really a task for the technician, not the executive. If the latter works through a simple example, he will have sufficient knowledge to exercise top-level judgment.

An Example

An example will be helpful in showing how the procedure may be employed in a practical application. While the variables will differ according to the nature of the problem, the procedure always will be the same.

The example is based upon a problem which vexed a long-established Connecticut manufacturer, John Smith & Sons Company. Smith, among a variety of other household appliances, produces a kerosene cook stove, of simple design, and a meat chopper, both of which are popular in Latin American countries among low-income families. Among these markets, Puerto Rico is not the least in importance. There is, of course, competition from several other American manufacturers, and an increasingly strong potential threat of kerosene cook stove imports from West Germany. There is no foreign threat to the meat chopper line. There is a tariff on imports into the United States and Puerto Rico of cook stoves, and Smith is somewhat hopeful that a quota may be imposed on American imports, but is not too sanguine about it happening soon.

Smith has heard a lot about how various mainland manufacturers have recently set up plants in Puerto Rico, and thinks that perhaps they should build a plant there to supply at least that local market with both the stove and meat chopper; production in Connecticut would be correspondingly decreased. Calculations show that a plant of practical size could sell its output locally, and that a $1.0 million investment would net the company $140,000 annually.[6] Hence the idea seems quite attractive, especially since the company has idle funds of this amount now invested in Government bonds which return only $20,000 per year. The base of the computations as to expected net income is that the Connecticut buildings made idle can be sold, and that present conditions as to competition, industry and tariffs will remain unchanged.

But Smith now is faced with the problem of finding, in dollars per year return on investment, whether or not the return is sufficient to warrant the risks of the venture if certain changes do occur. Smith must undertake what amounts to solving a series of simultaneous equations to find one final figure. The variables are these:

1. Effect upon present Connecticut plant if the vacated space is not sold as expected.
2. Effect upon a Puerto Rico plant if the industry-wide volume of kerosene cook stoves decreases. There is some indication that this product may be losing its popularity, being replaced by other types of stoves which Smith does not make nor intend to make.
3. Effect upon Smith Puerto Rican sales of these and other Smith products if a plant is built there.
4. Effect upon Smith's Puerto Rican sales if Smith does not build a plant there, but a competitor does.
5. Effect upon a Puerto Rican plant, if established, if imports of cook stoves from Europe should continue to increase.

While there are other intangible factors, Smith feels that the foregoing are the important points, and that the problems of personnel, local management, etc., can be coped with. Smith already has had experience in starting Latin-American plants and is aware of the intangible problems, which they consider minor.

In terms of game theory, the problem is a *2 x 6* matrix. The *2* reprexents the choice of *Build* or *Not Build*, since there is no other possible choice. The *6* represents the above five variables, plus the original expected condition. The matrix, or diagram, has as its initial variable column the data representing the assumed, or expected conditions on which the original profitability computations were made:

Choice \ Variable	Expected Condition
Build	140[7]
Not Build	20

The 20 for the *Not Build* choice represents the return that otherwise would accrue from present funds if not invested in the new plant.

Game theory employs the independent analysis of each variable, unrelated to the others at this stage, so each point is considered in turn. We need not be concerned with

[6] All income or loss data in the example are considered as being prior to deductions for Federal Income Tax.

[7] Data in all diagrams are shown in terms of thousands of dollars per year.

the computations, which are merely handled by customary accounting and engineering analysis procedures, and will indicate only the answers:

Effect of Not Selling Plant

If the cook stove and meat chopper volume were removed from the Connecticut plant, remaining products must absorb any residual fixed overhead, and this has already been taken into account in the $140,000 profit above computed. But, while the vacated plant space, an isolated building, probably can be sold, the property is not especially desirable and Smith might find that he is unable to sell. Smith then would be required to maintain, insure, and otherwise carry the property indefinitely. This would cost $32,000 annually, so that if not sold, the net annual profit would be only $108,000. The situation as to this variable diagrams as follows:

Choice \ Variable	Property Not Sold
Build	108
Not Build	20

Effect of Industry Decline

If the industry volume in kerosene cook stoves should decrease, independently of the effect of imports, operations in a new Puerto Rican plant would in time, of necessity, be curtailed. A reasonable assumption is that within the next decade this might be as much as 50%, in which case the unabsorbed fixed overhead there would amount to an estimated $23,000, thereby reducing the expected profit to $117,000. The diagram as to this situation is then:

Choice \ Variable	Industry Decline
Build	117
Not Build	20

Effect Upon Puerto Rico Sales

While Smith now does a substantial volume in both kerosene cook stoves and meat choppers in Puerto Rico, so do several competitors. It appears to be undeniable that a local plant would have a beneficial effect upon Smith sales by diverting a substantial part of competitors' volume to Smith. Also, the demand in the region, especially for meat choppers, is growing, and a local plant is much more likely to acquire a larger share of the increase than a remote mainland plant. If Smith builds, it is highly unlikely that a competitor will do so also. The estimates show that an additional $24,000 of profits can be expected within a few years, or that the profits would be $164,000 instead of $140,000. On the other hand, it is not likely that this additional profit can be secured if the Puerto Rico plant is not built, so that the *Not Build* decision would lose this potential profit of $24,000, less bond income, or a net loss of $4,000. Another diagram thus can be drawn:

Choice \ Variable	Puerto Rico Sales
Build	164
Not Build	− 4

Effect If Competitor Builds

If Smith does not build a Puerto Rican plant, but a competitor does, then the reverse effect of the foregoing can be expected. By the same logic as before, Smith would lose the profit which it now makes on the volume which would be lost to competition. A probable loss of profit, including unabsorbed fixed overhead at the Connecticut plant, is computed at $36,000, less the bond income, or a net loss of $16,000. The effect of both Smith and a competitor building is ignored, because in practice the first builder will exclude all others. This situation diagrams thus:

Choice \ Variable	Competitor Builds
Build	140
Not Build	− 16

Effect of Imports

The biggest unknown in the entire picture is imports. West Germany is making a drive to re-enter its former Latin-American markets, and is a serious threat to American producers of kerosene cook stoves, even if not of meat choppers. If imports should succeed in getting 80% or more of the cook stove market, as there is a real chance they might, the effect upon the new Puerto Rico plant would be nearly disastrous. If imports did increase to this serious extent, the Puerto Rico operation, instead of showing $140,000 profit, could be expected to show a $15,000 loss. Since best judgment indicates that the probability of a quota being imposed to restrict imports below the 80% of market level are at best 1 to 3, this loss statistically is diagrammed at three times as much, or $45,000:

Choice \ Variable	Imports Increase
Build	− 45
Not Build	20

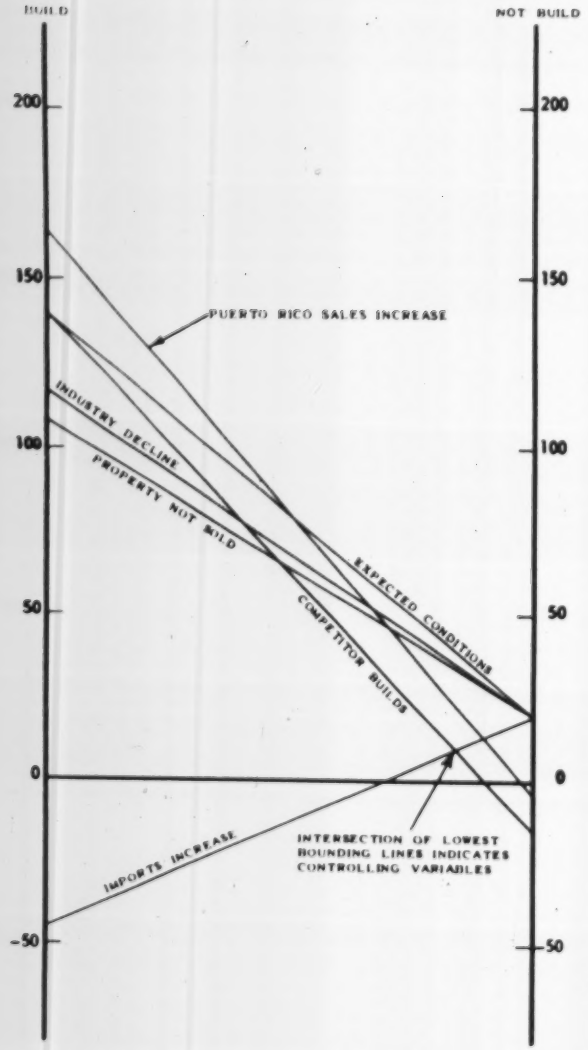

Fig. 1 Graphic Solution of 2 x N Game to Find Controlling Variables.

The various factors have now been considered independently, and the next step is to combine them:

Choice \ Variable	Expected Conditions	Property Not Sold	Industry Decline	Puerto Rico Sales Increase	Competitor Builds	Imports Increase
Build	140	108	117	164	140	−45
Not Build	20	20	20	−4	−16	20

The matrix is now complete, and the next step is to compute the odds. There is a simple method for doing this in $2 \times n$ games. First, the diagram is scanned for a *saddle-point* – a value which is the minimum in its row, and the maximum in its column.[5] If there were one, this would show the dominant variable and choice. The best possible choice would be that for the row in which the *saddle-point* lay. For, this would be the least profit that could be made under any circumstance. The only question then would be the managerial decision as to whether this profit was enough. Since there is no such easy answer in this case, we proceed to solve graphically, as in Figure 1. In this figure, for each variable n the proper values are indicated on the *Build* or *Not Build* vertical line, and a line drawn between the points.[6] The highest point on the lowest bounding lines indicates the governing variables. All others can be discarded. The odds and game value are computed on these two variables only – Competitor Builds, and Imports Increase:

Build	140	−45
Not Build	−16	20

The method of computation consists of merely subtracting the right-hand figure from the left:

Build	185
Not Build	−36

Disregard the sign, reverse the figures, and the odds are as follows:

Build	36
Not Build	185

That is, out of every 221 chances, only 36 times should Smith build, or, the odds are 36 to 185 against building successfully. The game value is computed by applying these odds to either variable (as a check, the answer must be the same for each):

$$\frac{(36 \times 140) + (185 \times -16)}{36 + 185} = 9+$$

Smith has only 36 chances out of 221 of being sure of making at least $9,000 per year out of a $1.0 million investment if the plant is built – quite a different story from the $140,000 return under the expected conditions. Should the project be abandoned? Not at all. This is only the first trial run.

The next step is to inspect the diagram, to find the reasons underlying the unhappy results. It is at once plain that the only losses in the *Not Build* row are caused

[5] Strictly speaking, a *saddle point* is that value which is the largest of the minimums in any row (maxmin) and at the same time is the smallest of the maximums in any column (minmax).

[6] Those mathematically inclined will at once recognize this as being merely the plotting of the equations $y = 140x + 20(1 - x)$, etc., in which x represents the *Build* choice, and hence $(1 - x)$ the *Not Build* choice and y the pay-off for this variable. The range of x is, of course, from 0 to 1.

by the failure to have a plant of any kind in Puerto Rico. That is, a plant there would, no doubt, keep out a competitor, forestalling any diversion of sales to him, and also have a beneficial effect on the sales of all Smith products. It is also evident that the only loss in the *Build* row arises from the threat of imports of kerosene cook stoves.

The solution is clear—have a plant in Puerto Rico, but do not make cook stoves there, only meat choppers. Smith then starts a new round of computations along preceding lines, to determine the feasibility of having a smaller Puerto Rican plant manufacturing meat choppers only. This is found to be possible from an operating point of view, with a smaller investment of $750,000 and a smaller $96,000 profit under expected conditions. The resulting diagram omits those variables exclusively concerned with kerosene cook stoves:

Choice \ Variable	Expected Conditions	Property Not Sold	Puerto Rico Sales Increase	Competitor Builds
Build	96	75	113	96
Not Build	15	15	15	−2

Since, for every variable the *Build* row is well in excess of the *Not Build* row, the choice is obvious, and since the minimum value in this row, $75,000, represents a 10% return on investment, Smith will build the plant. The decision is made with confidence, for it was based on true business judgment, assisted by logic and mathematics, and not dependent solely on hunches.

Measures of the Efficiency of Acceptance Sampling Plans

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and

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The overall effectiveness of a sampling plan is completely described by the operating characteristic (OC) curve. The difference in effectiveness of two sampling plans can be obtained by a visual comparison of their OC curves. Some other measures of effectiveness are Average Sample Number, Total Average Inspection, and Average Outgoing Quality (1). None of these characterize the ability of the sampling plan to discriminate between good and bad lots, which we will refer to hereafter as the efficiency of the sampling plan.

We have divided the efficiency of sampling plans into two groups, Producer's Efficiency and Consumer's Efficiency. Producer's Efficiency is somewhat similar to the complement of the familiar term Producer's Risk except the efficiency is no longer restricted to the single per cent defective of submitted lots denoted as the Acceptable Quality Level (AQL). This efficiency denotes the ability of the plan to accept submitted lots which should be accepted, in other words, those lots whose per cent defective can be any value from zero through AQL. It can be noted that the AQL as used in this article is not a per cent defective at which 95% of the submitted lots will be accepted but any quality level selected by management. Consumer's Efficiency is the ability of the plan to reject submitted lots in which the per cent defective is any value from AQL through 100%.

In this article tables are presented which give the Producer's Efficiency and Consumer's Efficiency for sampling plans in terms of the acceptable quality level (AQL), sample size (n), and the acceptance number (c). These tables enable us to determine the change in efficiency resulting from a change in any of these parameters of a sampling plan.

Definition of Efficiency

All submitted lots whose fraction defective is less than or equal to the AQL should be accepted and all submitted lots whose fraction defective is greater than the AQL should be rejected. The ability of a sampling plan to per-

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form this correct action can be determined from the OC curve.

There exists only a countable number of points of the OC curve. The number of these points and the corresponding ordinate values depend on the size of the inspection lot. If the lot contains N items, there exists only $N + 1$ points on the OC curve. The abscissa can then be expressed in terms of the number of defective items (m) in the lot, where m ranges from zero through N (Fig. 1). For each discrete m there is a corresponding probability of acceptance which can be determined in terms of the hypergeometric distribution. In a perfect sampling plan each of the probabilities of acceptance would be equal to one where m is less than or equal to N (AQL) and equal to zero where m is greater than N (AQL). This is not, however, realizable under sampling conditions.

The Producer's Efficiency (Ep) of a sampling plan (a measure of the ability of the sampling plan to accept lots which should be accepted) is defined as the ratio of the sum of the probabilities of acceptance which correspond to the discrete values of m where m ranges from zero through N (AQL), to the sum of the corresponding probabilities of acceptance which would be possible if the sampling plan were perfect. Thus:

$$\mathrm{Ep} = \frac{\sum_{m=0}^{[k]} \sum_{x=0}^{c} \dfrac{\binom{N-m}{n-x}\binom{m}{x}}{\binom{N}{n}}}{[k]+1} \qquad 1.$$

Where: $\binom{p}{q} \dfrac{p!}{q!(p-q)!}, \quad p \geq q$

$[k]$ is the largest integral value for m which is less than or equal to N (AQL).

x is the number of defective items in the sample.

The Consumer's Efficiency (Ec) of a sampling plan (a measure of the ability of the sampling plan to reject lots which should be rejected) is defined as the ratio of the sum of the probabilities of rejection which correspond to the discrete values of m where m ranges from $N(\mathrm{AQL}) + 1$ through N, to the sum of the corresponding probabilities of rejection which would be possible if the sampling plan were perfect. Thus:

$$\mathrm{Ec} = \frac{\sum_{m=[k]+1}^{N} \sum_{x=c+1}^{n} \dfrac{\binom{N-m}{n-x}\binom{m}{x}}{\binom{N}{n}}}{N-k} \qquad 2.$$

Where: $[k] + 1$ is the smallest integral value for m which is greater than $N(\mathrm{AQL})$.

Method of Calculations

Assuming an infinite lot size, the number of points through which the OC curve is drawn increases and the

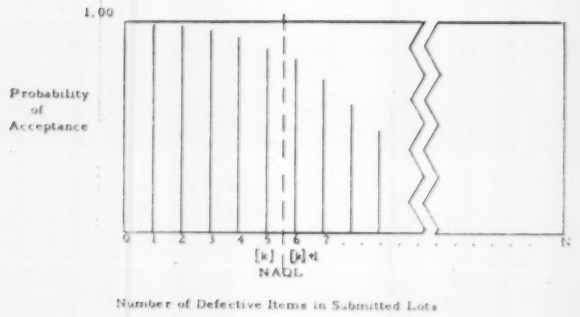

Fig. 1 OC Curve Showing Finite Points

OC curve is approximated by a continuous distribution. Letting $np = u$ and using the Poisson distribution as an approximation to the hypergeometric distribution, it is possible to restate equations 1. and 2. as follows:

$$\mathrm{Ep} = \frac{\int_0^{n(\mathrm{AQL})} \dfrac{1}{n} \sum_{x=0}^{c} \dfrac{u^x e^{-u}}{x!}\, du}{\mathrm{AQL}} \qquad 3.$$

$$\mathrm{Ec} = \frac{(1-\mathrm{AQL}) - \int_{n(\mathrm{AQL})}^{n} \dfrac{1}{n} \sum_{x=0}^{c} \dfrac{u^x e^{-u}}{x!}\, du}{1-\mathrm{AQL}} \qquad 4.$$

Further simplification produced:

$$\mathrm{Ep} = \frac{\dfrac{1}{n} - \sum_{x=0}^{c} \dfrac{1}{n} \sum_{x=0}^{c} \dfrac{u^x e^{-u}}{x!}}{\mathrm{AQL}} \qquad 5.$$

$$\mathrm{Ec} = \frac{(1-\mathrm{AQL}) - \sum_{x=0}^{c} \dfrac{1}{n} \sum_{x=0}^{c} \dfrac{u^x e^{-u}}{x!}}{1-\mathrm{AQL}} \qquad 6.$$

Where the values for the summation terms can be obtained from Molina's tables (2).

The graphs included in this paper were drawn from points calculated in this manner.

Examples of Use

1. To determine the Producer's Efficiency and Consumer's Efficiency of an existing sampling plan:

On the figure corresponding to the given AQL, locate the sample size along the abscissa and move vertically to the line corresponding to the established acceptance number (c). The efficiency is read from the ordinate for both Producer's Efficiency and Consumer's Efficiency (Straight-line interpolation may be necessary).

Example: Given, AQL 1.5%

$$n = 200$$

$$c = 6$$

See Fig. 4 and locate sample size of 200. Move vertically

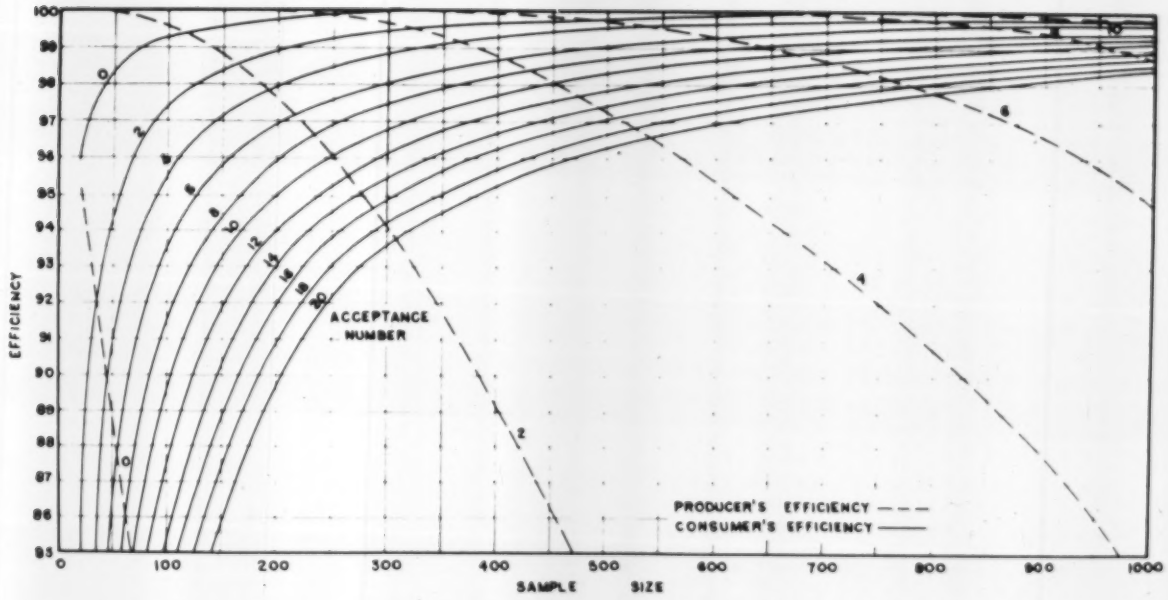

FIG. 2. Producer's & Consumer's Efficiency of Sampling Plans with Acceptable Quality Level of .5 Per Cent

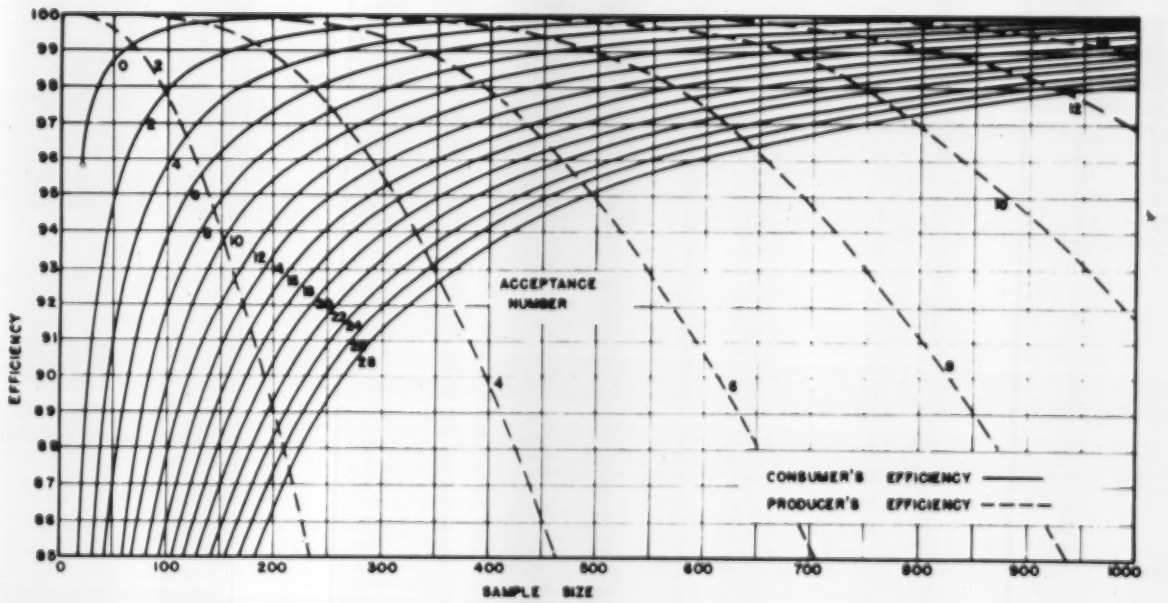

FIG. 3 Producer's & Consumer's Efficiency of Sampling Plans with Acceptable Quality Level of 1 Per Cent

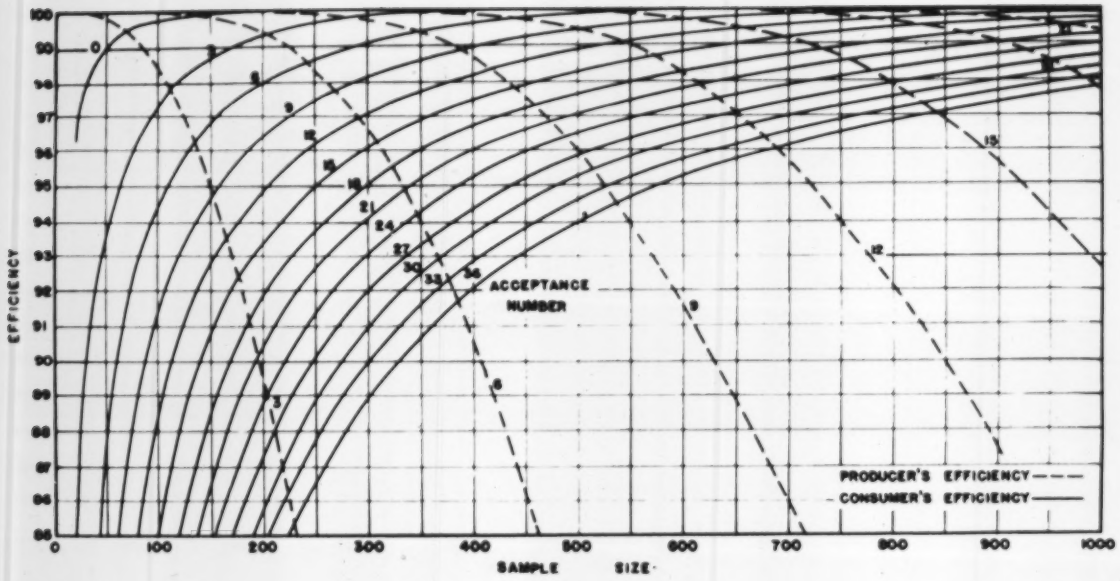

FIG. 4 Producer's & Consumer's Efficiency of Sampling Plans with Acceptable Quality Level of 1.5 Per Cent

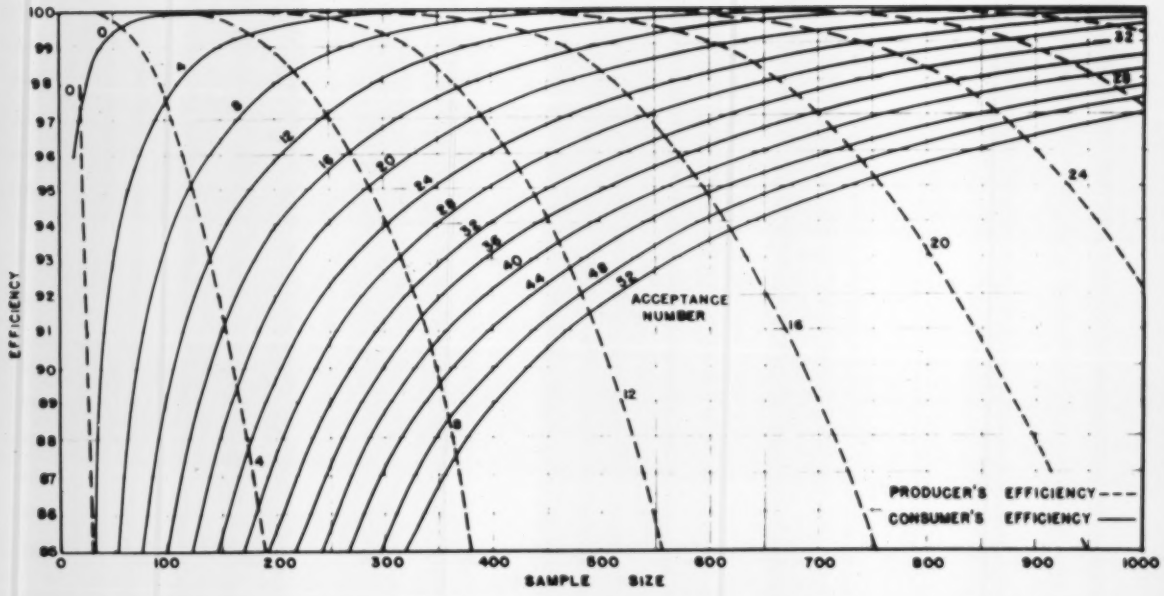

FIG. 5 Producer's & Consumer's Efficiency of Sampling Plans with Acceptable Quality Level of 2.5 Per Cent

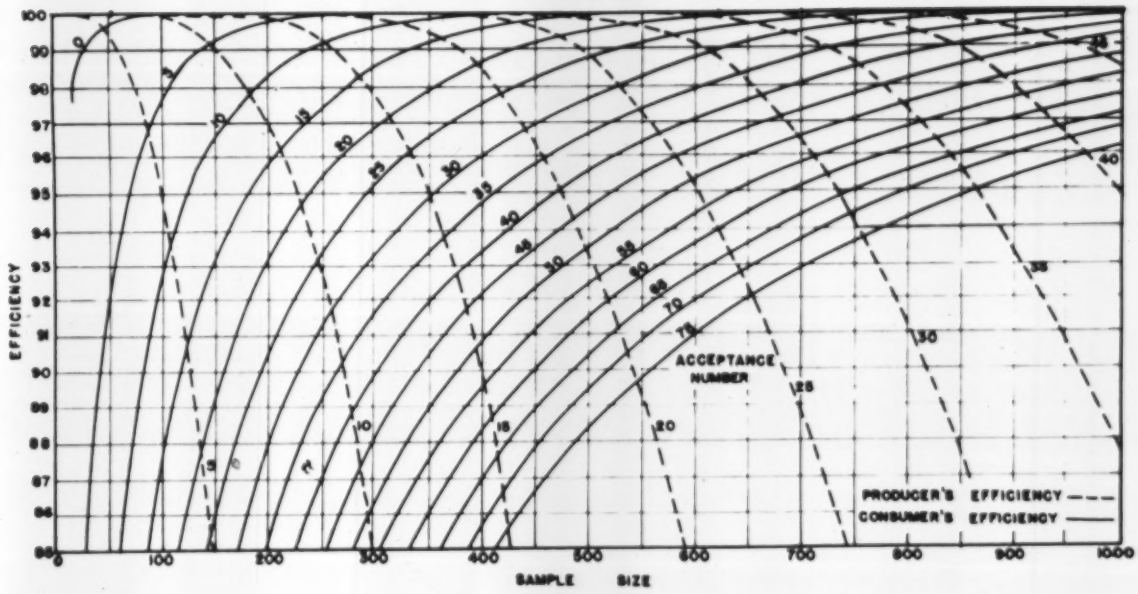

Fig. 6 Producer's & Consumer's Efficiency of Sampling Plans with Acceptable Quality Level of 4.0 Per Cent

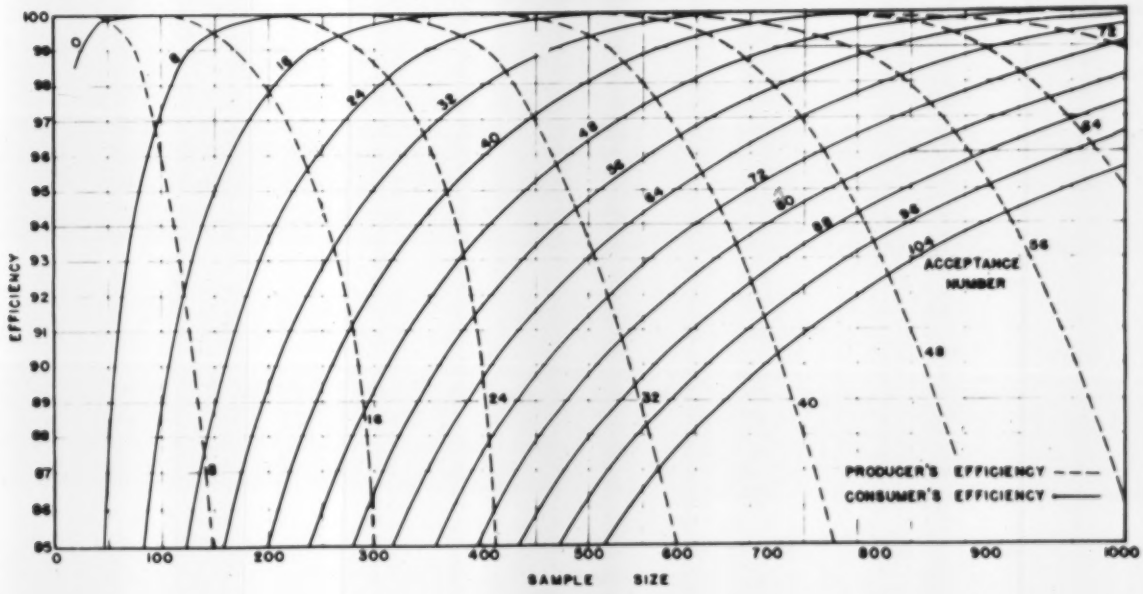

Fig. 7 Producer's & Consumer's Efficiency of Sampling Plans with Acceptable Quality Level of 6.5 Per Cent

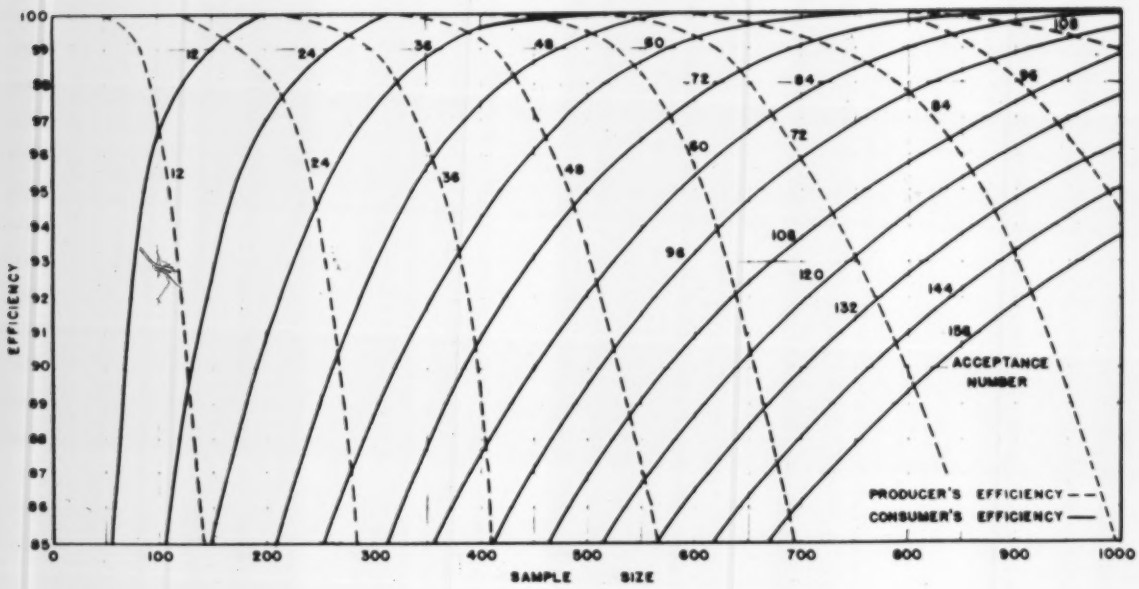

FIG. 8 Producer's & Consumer's Efficiency of Sampling Plans with Acceptable Quality Level of 10 Per Cent

to solid line at $c = 6$ and read Consumer's Efficiency (.98). Move vertically to dash line at $c = 6$ and read Producer's Efficiency (.993).

2. To determine change in efficiency resulting from change in AQL, c, or n.

2.1 Given AQL or 6.5% and c of 8

The lines corresponding to c of 8 should be located on Fig. 7. The change in efficiency resulting from change in sample size can be determined.

2.2 Given AQL of 6.5% and n of 300

Locate the n of 300 on abscissa of Fig. 7. Efficiencies resulting from various c numbers can be determined by noting where the c lines cross the n line. (straight-line interpolation may be used as necessary)

2.3 Given n of 300 and c of 32

Begin with Fig. 2 and note the efficiencies corresponding to these points. Continue this process on the following Figs. as desired.

3. An interesting sample size is that one which, for a given AQL and given c, will produce a Producer's Efficiency which is equal to the Consumer's Efficiency. For example, AQL = .5%, $c = 2$, then $n \doteq 160$ will give Ep = Ec = 98.5%.

Conclusions

The use of these tables permits analysis of the increase in efficiency of a sampling plan resulting from a change in acceptance number, acceptable quality level and sample size. This should prove more effective than drawing the OC curves and visually comparing these curves.

It should be noted that the term Efficiency as defined in this paper is dependent upon all per cent defectives (from zero through one) being equally likely. While this somewhat restricts the term of efficiency it in no way restricts the use of the efficiency values as a basis of comparison between sampling plans, for these values reflect the change in OC curve resulting from a change in a given parameter.

This article should bring to mind several problems. One being: how efficient should a sampling plan be? Another could be: how should the efficiency be divided between producer and consumer? It is evident that there should be more research along the lines of analysis of the economic factors involved in producing good and bad items as there is no way to produce only good items.

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An Industrial Engineer Looks at Production Designing

By Edwin Whitehead

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The success of any manufacturing enterprise will be determined to some extent by the cost of manufacture of its products. Accordingly, the design of the products to permit low production costs is part of the problem of the design of the enterprise as a whole. The problem is of a two fold character. First, it must be determined what conditions will permit low cost production and second, what features of design will permit these conditions to be realized. Available processes and manufacturing machinery must be taken into account in determining features of design which will permit low cost manufacture. One of the conditions which permits low cost manufacture is that which results in the most rapid turnover of working capital. Therefore, those features of product design which contribute to reducing the time of forming or processing the products are most desirable in providing for the economy in manufacture. The products of manufacture vary so greatly in their methods of production that what may be accomplished specifically in each case, with respect to economy of manufacture, depends on many factors. In the case of machine products, it is found, in general, that economy of manufacture depends upon the time of set up of the parts in the machine and the time taken to perform the operation. These time factors are influenced by:

1. The limits of dimensions or tolerances to which the product is to be machined.
2. The material specification, hardness, and general machinability.
3. The adaptability of the design to the use of rapid and multiple processing machinery.
4. The interchangeability of similar parts in a series of sizes of products.
5. The use of standardized units such as bolts, studs, and similar parts.
6. The use of a minimum number of sizes of units from which the entire line of products is manufactured.

All these features have to be considered in producing drawings which are the expression of the design; therefore such drawings must be prepared with the greatest care. The design of every form of product should be carefully checked with regard to the above points, and the design corrected if necessary before the machinery for processing is selected, because changes in design frequently suggest changes in methods of processing and the machinery to be used. The limits of dimension to which parts must be machined often determines the type of machinery to be used in manufacturing. If the limits are very narrow, with the dimensions to be held to plus or minus three ten-thousandths, and the part is to be round, a certain type of grinder is required, whereas if the limits are not so close, certain types of lathes may be used. As limits of dimension become closer, the cost of manufacture increases. The rate of production will also be controlled by the design specifications, particularly by the limits of dimension, which must be adhered to, and by the kind of jigs and fixtures which can be used accordingly. The number and types of machines for a given rate of production cannot be decided until these features of design have been fixed.

PURPOSE OF PRODUCTION DESIGNING

The production design must be such that all necessary production operations can be performed readily on the manufacturing equipment that will be available. Here we have two possible conditions to consider. First, if it is to be produced in a new plant for which manufacturing equipment is to be provided as required there are few, if any, restrictions placed on the choice of the processes to be employed in production. Secondly, if the new commodity is to be made in an existing plant, the choice of process to be employed is limited to a great extent by the capacity of the existing manufacturing equipment. *In either case, the details of the production design should be controlled largely by the production methods to be employed.* This requires that the production designing be done in close co-operation with the industrial and production departments, when the selection of manufacturing processes is being made. Often, a minor change in size or shape of some part of the product makes possible a material saving in the cost of productoin.

SIMPLICITY OF DESIGN

A primary object of the production design should be to simplify the construction of the proposed products as much as possible. Simplicity is always a source of economy. This holds true for both the product itself and the manufacturing processes used to make it. In fact, simplicity is an acid test of achievement in every line.

No design or process can be considered as finished until it meets the test of simplicity and effectiveness. Another important function of the production design is to so arrange the mechanism that it requires a high order of accuracy on as few surfaces as possible. Critical study will show that, in almost every mechanism, there are a few important and essential surfaces and inter-relations, but that the great majority of them are relatively unimportant in this respect. The essential part of a watch is its escapement mechanism. If this be good, the watch will be accurate, but the escapement is only a small part of the watch. Furthermore, in the escapement itself, there are some relatively unimportant details. The remainder of the mechanism of a watch is usually a train of gears with a spring to drive them. The character of the requirements of this larger part of the mechanism is not nearly as severe as those for the escapement. Thus the manufacturing design should always strive to keep the need of severe requirements to a minimum.

CLEARANCES AND TOLERANCES

Another important function of the production design which is closely allied to the preceding one is the development of a design that can permit liberal tolerances. Clearances should be one of the principal considerations in developing a production design. This should aim to allow the greatest possible amount of clearance between companion parts. The more the design lends itself to this end, the greater variation of tolerances that can be permitted, and hence the greater economy of production, also, the greater degree of interchangeability of parts that can be secured. Clearances are vital factors in inter-changeability, but the latter cannot be maintained without proper clearances. It is self-evident that a certain space must be left between operating parts. The minimum clearances should be as small as the assembling of the parts and their proper operation under service conditions will allow. The maximum clearances should be as great as the functioning of the mechanism will permit. Every operating part of a mechanism must be located within reasonably close tolerances in each plane. After such requirements of location are met, all other surfaces should have liberal clearances. An important consideration in establishing the manufacturing requirements of any commodity should be to determine and define the essential requirements first, and let the non-essentials take care of themselves later. *Full economy in manufacture requires that due care and pains be taken where necessary, but that all un-necessary refinements be omitted.* The essential requirements need, and should, receive the greatest attention. This, however, is seldom done. All machine surfaces on all parts are often considered of equal importance. The results of such practice are that the essential points do not receive the attention they need, while the non-essentials receive more than they require, thus resulting in the production of an inferior product at a higher cost than a superior product would cost with the proper division of attention.

UNIT ASSEMBLY

Another object of the production design should be to arrange the mechanism so that as many units as possible can be made independently. Almost every mechanism can be subdivided into smaller units which are distinct in their every purpose. For example, a refrigerator contains a motor, compressor, freezer compartment, coils, etc., which are first assembled and tested as units, and later assembled into the completed refrigerator. In like manner, an electric hand drill is subdivided into the chuck, transmission, motor, housing, and switch, etc. Both the assembling and final testing of the completed products are greatly facilitated if the design permits such unit construction, and efforts should be made to obtain this result whenever possible. There are many other advantages of the unit assembly construction. Not only the various manufacturing departments of one factory, but also entire plants are specializing more and more. Where such unit assembly is of equal value on several articles, separate plants are created to produce them as specialities. *This, in turn, makes possible quantity production, where otherwise it might not exist.* Another object of the production design should be to standardize the sizes and shapes of as many machine surfaces as possible, and reduce their variety to a minimum. This practice has a very direct influence on the economy of production.

SELECTION OF MATERIAL

The materials selected for each of the parts to be produced have an important influence on the cost of production. The use of welded units or sheet metal stampings in place of sand castings and of molded plastics for metal machine parts frequently results in not only a reduction of material cost but also in lowering machining and assembly costs.

I cannot emphasize too strongly the use, where possible, of the free machining steels. An extensive effort should be made to obtain uniformity of heat treatment of products to be machined, together with the annealing of the tougher metals to ensure uninterrupted production flow. A surprisingly large number of companies who purchase their castings from an outside source duplicate the service rendered by the foundry by machining and performing full tests on test bars drawn from different metal heats. An expensive and uneconomical process. The services and uses to which the parts are to be subjected should be clearly determined, and the most economical material which will serve the purpose should be specified. Not only should the cost of the material itself be considered but also the cost of fabricating it.

DESIGN BALANCE

Oliver Wendell Holmes, in his poem "The Deacon's Masterpiece" or "The Wonderful One Horse Shay", sets forth a principal of balanced design. It will be remembered

that all parts of this vehicle were so well proportioned with reference to each other (all were equally strong) that when it broke it broke all over, not one piece, but all pieces, so that it appeared as if it had been to the mill and ground. "It went to pieces all at once and nothing first, just as bubbles do when they burst." *Products designed for balance in strength, performance, and wear, are generally of maximum utility at a minimum cost.* If an army rifle is designed with very close limits of dimension of the parts of the barrel and firing mechanism, the increase in cost occasioned by manufacture to close limits of dimension of these parts is lost if the sighting attachments are designed to rougher limits. So that the accuracy and performance of the rifle as a whole is not satisfactory.

A drill press designed to drill 4" diameter holes through steel plate need not have a column, spindle bearing assembly, transmission, motor, etc., safer and stronger than he load requires. If a bus engine will last for 70,000 miles and the chassis is worn out after 30,000 miles of use, the design of the bus is not well balanced. A shoe designed so that the heel wears out very rapidly while the sole is many times more durable is not a well balanced design. A jet aircraft with weak hydraulic pumps may be forced to land, or even be destroyed, yet the design in all other respects may be good. Products out of proportion with respect to relative utility or reliability of their parts are not economically designed, and hence are not competitive with products of better design with respect to balance. Products of unbalanced design constitute hazards to the business, and while they may not cause its failure, they may reduce profits. Accordingly, one of the ways in which an economical balance in design can be assured is by checking each part exhaustively before the design is approved to see that none are unnecessarily heavy or are out of proportion to other parts with respect to performance, wear, strength, and other qualities.

Preparing for Paperwork Automation

By Ben S. Graham

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Preparing for Paperwork Automation sounds like a harmless but rather routine and perhaps technical process.

But, how we approach it may increase our profits 50 to 100% or continue to further stifle progress with the growing burden of paperwork.

What do we mean by Paperwork by Automation?

Paperwork Is?

Paperwork, as defined by many groups I have worked with, is the recording, storing, analysis and reporting of information, sometimes facts, for only one real reason, to help someone do his job better. This is true whether it is to let the janitor know when to clean an area, what material and equipment to use or whether it is to have the information for the board of directors five years from now to help them decide whether to add new products, increase productive capacity, expand sales force or territory or what not.

The recording may be by pencil, machine, holes in tape or cards or magnetic impulses. Storing may be on paper, by holes or magnetically. Analysis may be manually on a multi-column sheet, by machine or electronically. Ultimately, information has to be presented in the proper form for people to use.

Automation Means?

Automation means different things to different people. Some claim that the automatic machining of the automobile engine block is not automation because when an operation gets out of limits, the whole machine stops and waits for the people to correct the error. It does not include feed back control which corrects the error and permits continuous operation. Automotive engineers labeled the process "automation" when it was developed. There are varying degrees of mechanization from the machine assists to man, to the highly automatic processes found in the petroleum or chemical industries incorporating many self correcting abilities.

Regardless of the degree of mechanization or self control

built in, automation involves automatic production by machines of a product that is worth producing. The last phrase—"a product that is worth producing"—is the key to success in preparing for Paperwork Automation.

Paperwork Problems

For years too many office people have purchased machines to solve their problems in paperwork. They have seen the tremendous progress made in production through mechanization. But they have often not recognized the study that preceded the development of machines to do a necessary production job.

The result has been too much mechanization for the sake of mechanization without first determining the needs.

There are plenty of problems which seem to justify this mechanization. Today many sections of our country are faced with a shortage of clerical personnel. Clerical employment in industry has increased from one clerk to 10 production workers to one clerk to three production workers in the last half century. Last year non-productive paperwork costs equalled 20% of our national product or 80 billion dollars. Value of product per production worker has roughly doubled while the value of product per clerical worker has remained the same.

On the face of it, all of these would seem to point to the need for more mechanization in the paperwork function particularly when we observe the results in production.

But let's take another look.

There is a company in which the production workers produce $37,500 of product per worker per year. This is exactly three times as much as the other companies in their industry average. In that same company, each clerical employee handles the paperwork for about $400,000 of product or about eight times as much as their competitors clerical people. Nationally the average is about $47,000 of product per clerk and has been the same for many years.

Eliminate Waste

If we will apply the test "a product that is worth producing" or "does it help someone do his job (one that is worth doing) better" to our paperwork, I am convinced we will find that about half, or what is costing 40 billion dollars, will not measure up.

This waste varies from paperwork that is no good to anyone to the systems that cost more than the value derived. In recent years, I have persuaded a number of companies to gather and display all top level reports for critical examination by management. Invariably this discloses duplicate or obsolete reports comprising from 10 to 30% of the total. Reports initiated years ago for a one time use have been perpetuated. Almost invariably duplicate information, systems and reports are discovered being maintained in independent, autonomous divisions or functions of the company. It is not at all uncommon for officers to not recognize reports that have been prepared exclusively for them for years.

Such an examination by management, when followed by action, produces prompt and substantial savings, but it only scratches the surface. A tremendous by-product is the effect on the employees. While obvious waste is tolerated at the top, there is little incentive for workers to save or even be concerned about doing a day's work.

Stimulate Interest

Actually there is far more satisfaction in doing a good day's work than there is in soldiering, if the work is appreciated. When top management eliminates waste, workers will believe their cooperation is really wanted.

However, it is still pretty difficult for the credit clerks, checking customers' orders to see if the credit is good, when 90% of the orders come from Sears Roebuck, Montgomery Ward and Western Auto. Any clerk knows he would be fired for rejecting one of those orders. Yet management in that company complained about the burden of paperwork, how government regulations increased the load and how hard it was to get competent clerks. Why should any one of those credit clerks be concerned about anything except their pay check when management assigned them to a job that was 90% waste.

How many of the journals, records and reports at intermediate and lower levels are defensive records maintained to prove that the job was done?

Production for Profit

In preparing for paperwork automation, we must get back to fundamentals. First we must impress many of the highly technical specialists we have developed that in our economy business is operated not as a proving ground for techniques, but to make a profit. Profit is the only foundation for material security which we all would like, and profit only comes from production that is useful to someone and can be sold. Each individual has a responsibility to produce, to help make a profit, to assure his own security and preserve his freedom. When we fail to accept and discharge responsibility, we pay for it by sacrificing freedom.

A New Concept

We must take a new look at our controls. Paperwork controls nothing. Paperwork will provide information to people to help them control material things. People exercise little control over other people, frequently not much over even themselves. But controls properly conceived can be goals—incentives that people will strive to achieve.

Controls should warn of impending disaster so that we can avoid the loss rather than tell us how badly our costs, quality, sales, etc., fared last month.

In cost control, for example, when we plan and schedule production, we determine the labor, machine and material cost. If we meet schedule and have no overtime, our costs will be within limits. The signal that trouble is ahead is a request for overtime. Too much scrap, poor material, excessive machine downtime may be the cause. The request for over-time is the signal to find out why and correct it *before* the damage is done—not after.

Such an approach to all our control functions can eliminate tremendous volumes of detail paperwork that is serving no real purpose.

Recently a large company investigated the cost of collecting shipping charges they had paid on materials received from vendors when the purchase was made on the basis of prepaid charges. They found they had collected two hundred thousand dollars in the previous year but it had cost them two million dollars to collect it. Too much control was wasting $10 for every dollar saved.

To automate a report the president doesn't recognize because his secretary has been filing it for years; to automate the checking of credit on orders from Sears Roebuck; to automate the tremendous volume of detail distribution in the usual approach to most controls or to pay $10 to collect $1, automatically or otherwise, will compound the felony and perpetuate the waste.

Effective automation can only come when we examine and determine our needs.

Frequently to automate means to standardize; molded plastic chairs can be manufactured automatically. Prefabricated house manufacture is highly mechanized. But plastic chairs and prefab houses don't suit everyone and every situation.

Your situation merits its own solution, not regimentation.

First, study your paperwork to get rid of the waste, both systems and due to lack of interest of the people.

Second, determine your equipment or hardware needs and specify them.

Third, if economic then install the hardware.

Doing It the Hard (Expensive) Way

Recently the controller of a large company related this experience.

The president of the company had visited one of their large manufacturing and research installations. While there, he was shown their research computer. It might as well have been a boiler room with the gauges, lights, bells and whistles. When the president returned home he ordered a computer for the head office.

Talking with the controller, the president asked if the controller had a computer. The answer was no, but a study was being made to see if there was a need. The controller asked the president what was to be done with the computer already ordered. This led to the appointment of a top level committee to study the company systems from beginning to end.

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If that is the only way to break down barriers in a company, penetrate the empires, get rid of the sacred cows, then I am all for it, but it is too bad that we must follow that process so often.

The Sound Way

In preparing for paperwork automation, we must first get the water out of our systems, eliminate the waste, and in doing it make savings equal to or even in excess of our annual profits. The next step is to determine our needs for equipment. Finally, if the equipment is available and can be justified by further savings, install it.

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The early portion of the book serves as a general introduction. Topics discussed include the history of work sampling, its fundamental statistical concepts, a discussion of control charts, some practical suggestions for determining sample size, and demonstrations of how sampling works. Mr. Barnes also shows how to use random number tables, the procedures involved in making a work sampling study, and how to determine time standards by work sampling.

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By J. M. MacBrayne

Vice President, Southeastern Region, AIIE 1956-57

Some people call our time the age of chemistry, some the age of the atom, some the age of glass, the age of petro chemicals, or the age of you name it. Put them all together and you have the age of engineering. All you have to do is look about you at our new cars, our communications, at our new home appliances, at our weapons of defense, at the complicated mechanical brains which can do our thinking for us better than we can, and we find that whether we like it or not, we are completely dedicated to this age of engineering.

Lewis L. Strauss, Chairman of the United States Atomic Energy Commission, said that if there is to be another war among nations of the world before the human race discovers a method of abolishing recourse to combat, that war may be survived by the country with the greatest stockpile of nuclear weapons and instruments of their delivery. But such a war will almost certainly be lost by the country with the fewest resources in trained manpower.

Recently President Eisenhower said, "In this age of accelerated technological progress, our needs for engineers to help maintain the national security and to promote the national welfare is continually expanding. This fact gives rise to one of the major problems facing America the problem of maintaining an adequate flow of qualified young people into our engineering colleges." At the present time we are turning out less than one half the number of scientists and engineers that we require. Our economy requires from 45,000 to 50,000 newly trained engineers each year, and we are getting only 23,000. In 1950, eight college students came across the graduation platform to accept diplomas before one engineer came. By next June the number will be fifteen. On top of this only 65 per cent of all engineers who have graduated are actually engaged in the engineering profession. Only about 16 per cent of the high school graduates entering college each year enroll in engineering courses. This amounts to about 66,000 individuals. Unfortunately, more than one half of these young hopefuls flunk out along the way or switch to other courses. Most deans of engineering schools explain that this problem is based on poor high school preparation in science and mathematics. Our institutions cannot supply the scientists and engineers they need if students do not come to them with genuine ambition to be scientists and engineers and are not properly prepared in high school for such careers.

Unfortunately, the decisions that produce our skilled scientists and technicians are made for the most part well before the individual arrives on the college campus. Many high school students in the country have no opportunity to discover whether science and engineering appeal to them because preparatory courses are not available or are frequently taught by instructors whose interests or training lies in other subjects. Some 250,000 to 400,000 high school students in our country presently are being taught mathematics by teachers not trained to teach it. A recent study at Purdue University shows that the impressions of more than 15,000 teenagers with respect to science and engineering is amazing if nothing else. This survey, for example, indicated that forty-five per cent believe their school background is too poor to permit them to choose science as a career. Unfortunately, this is probably so. Thirty-five per cent believe that it is necessary to be a genius to become a good scientist. Thirty per cent believe that one cannot raise a normal family or enjoy life and be a scientist at the same time. Twenty-five per cent think scientists as a group are more than a little bit "odd". Fourteen per cent think there is something "evil" about scientists, and that you cannot be a scientist and be honest.

Last June, teachers' colleges and other institutions producing teachers in the nation graduated less that 250 teachers of physics for our secondary schools, and one half of these were attracted by government and industry away from teaching. At the present rates of education, we will train only one half the number of science teachers we will need to stay where we are during the next five years. We have a shortage of science teachers first, as a result of their being attracted to more remunerative fields; and secondly, as a result of inadequate emphasis and status given to science in our secondary schools. If we are to make a headway in educating more teachers of science and improving the teaching of science, the schools of engineering must do more than they have done so far to help to encourage more of their students to go into secondary teaching. M. I. T., among other engineering schools, is

* Based on a presentation to the Exchange Club of Savannah on February 4, 1957.

taking steps to encourage teachers of science. Jointly with the Harvard Graduate School of Education, it has established a five-year program designed to prepare students of science and engineering for teaching in secondary schools. It has provided special scholarships for students to enter this course.

In Russian high schools, of the courses which every student must take, 40 per cent are in science and mathematics. Ivan goes to school six days a week; and by the time he completes high school, he has completed six years of biology, four years of chemistry, and four years of mathematics including trigonometry. This sounds a little frightening, doesn't it, but this is our competition. Half of our high schools do not teach chemistry. Two generations ago in 1890, one in every five studied physics, and today it is one out of every 22. More than half of all students back in those days studied algebra, and now it is only one fourth. The study of chemistry has fallen off 30 per cent. Last June Russia produced 53,000 new engineers compared to our 23,000. The fact is that the sciences have an over-riding priority in Russian education. More than one half of the university graduates are in the science or mathematics field. Those of you who watch television may have seen the story about Israel and the importance they are placing on science in their fight for existence.

These, then, are the facts – what is to be done about them? There is no group more aware of the problem of the engineering shortage than industry, and in many cases industry has been guilty of using engineers where engineers were not absolutely needed and in attracting engineers and scientists from our schools and colleges. Some industrial concerns are now making greater use of technicians and non-engineering graduates to do that part of the work formerly being done by engineers where the highest skills were not being used. Many companies are assigning graduates of liberal arts schools to industrial problems formerly handled by engineers. The technicians are generally developed from the ranks of employees and are people with mechanical aptitude who can be trained to do some of the basic fundamentals of engineering. Typical of this development is the program recently worked out between Union Bag-Camp Paper Corporation and Armstrong College under which Armstrong gives the potential technicians the courses which it is set up to teach and Union Bag-Camp engineers teach the specialized courses necessary to round out the program. These courses lead to Associate in Science Degrees and not only help the development of our people but provide skills so desperately needed. Many companies are providing scholarships for teachers of science subjects in order to upgrade the teacher's proficiency and many companies are employing teachers of science during the summer in order to make up the difference between their teaching pay and the pay they might command in industry. I am sure that you will see such programs continued and enlarged. David Sarnoff, Chairman of the Radio Corporation of America, has proposed the establishment of a national educational reserve comprising qualified teachers in mathematics, physics, chemistry, and engineering to be drawn from the technological ranks of industry.

The Federal Government must also do something about this problem. The session of the 85th Congress now in session may be one of the most significant in years for the engineering profession. Of the more than 2,000 bills that have been introduced, a very substantial number deal with directly or affect the engineering profession, and increasing the supply of engineers and scientists. One of these bills would provide for loans to enable needy scholastically qualified students to continue post high school education. All too frequently the youngster of exceptional intellectual ability is the underprivileged youngster in our schools. One third of the top 2 per cent of the graduates from our high schools are not going to college – while some of them are not motivated, some of them do not have the means.

The professional societies are, of course, very much aware of this problem and have been trying to make it known to people in general through programs like this. More specifically in the Savannah area, the combined professional societies spearheaded by the American Institute of Industrial Engineers are making plans to offer the talents in these societies to the school system in any way that they may be of value in stimulating the youngsters' interest and knowledge in these important fields.

Our schools are all too aware of this great problem, probably more so than anyone else. As you know, one of the great problems is the lack of funds. With our rapidly growing population, it is practically impossible to keep our heads above water, let alone improve the facilities in any one area of education. It is very gratifying to see that Armstrong College is planning the expansion of its science facilities and these are certainly badly needed in the community. Needless to say, I hope that all of you and your companies will be able to help in some way this fine cause in our community.

Now we come to you and me as citizens and parents. What can we do about all this? In the first place, take an interest in education. Support your school system and attend the meetings of ACE, the Active Citizens for Education Committee.

When youngsters come to you for advice about college – as I am sure they will – make sure that they get all the facts from a qualified source, including what they need in the way for preparation in engineering or in any other career. While I do not expect that you will try to make an engineer of every youngster who comes along, I do hope that you will tell them of the importance to the nation of the work that engineers do, to insure them that they are not poorly paid and that engineering offers a career of great personal satisfaction. Take an interest in your children's work at school; encourage them to do good work. The kids say math is a hard subject. In order to qualify for an engineering school, it is necessary to pass with credit all the math courses ordinarily given in our high schools. Some physics or chemistry are also required. Now many

schools today do not make a boy do anything he thinks is too hard. It is true that some people have a bent for mathematics and science and some have not, but there are no courses in mathematics or science given in high school which a youngster of normal I.Q. cannot handle. Therefore, if you have normally intelligent children in high school, don't let them drop math. Some teachers claim the trouble arises in the grammar school, because if they have not learned the arithmetic in the grade school, they will have trouble with algebra and geometry and so watch that too. We have heard a lot about why Johnny can't read, but if Johnny can't add and Johnny is not a block head, there is something wrong and Johnny's dad should find what it is and fix it. No high school student loses anything by excelling in mathematics and science. If he finally decides to be a clergyman, journalist, merchant or actor or chooses any other calling, time spent in math will not be wasted. But unless he does excel in these courses, he will never be a good doctor, engineer, or any other scientist. The future is restricted by his lack of essential preparation. Guard your young friends and children so that when they are graduated from high school, their choice of a career is wide open. If they decide not to study engineering, let it be because they prefer something else and not because they can't get into an engineering school. This applies to girls as well as boys for there are equally rewarding opportunities in science and engineering.

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The Internal Consulting Functions of the Industrial Engineer*

By Wilson J. Bentley

Professor of Industrial Engineering and Management, Oklahoma A. & M. College, Stillwater, Oklahoma

I would like for Industrial Engineers to be thought of as *those professional engineers who help managers manage*. This pre-supposes a growth in the individual's outlook from that of "practitioner of time-study", for instance, to a technical-commercial-human relations management oriented type of viewpoint. This growth may require an entirely "new fitting of shoes". This viewpoint is one which requires a concept of management-as-a-whole (not as a conglomerate of techniques). It results in the individual considering the *whole* situation (all of the ramifications); a crystallization of the principal objectives; then an analysis of what needs to be done; and finally, taking indicated steps to see that it is done.

Management

To think as I have just suggested, one needs to decide upon some definition of management. As is true of most commonly used words the term "management" means different things to different people. Some people think of it as being that group of people who do *not* belong to the Union. Others think of it as a small group of executives at the very peak of an organization. There are others who think of the term as representing some rather hazy group from which all directions come. The word has taken on the representation of a group of people. In contrast to this conception I would like for you to think of the term in another way. *Management is the activity of maintaining the system of coordination of human activities known as an organization*. You will note that this definition has *one principal ingredient*, and that is *human activities*, or *people*. You don't manage machines or things, but you manage human activities.

Organization

The phrase, "system of coordinated human activities" can be more simply referred to as *an organization*. To promote a successful organization it is necessary to have an understanding of the three ingredients that must be present. The three are: 1. *common purpose*, 2. *willingness to serve*, and 3. *communication*. These ingredients must be poured into the pot somewhat simultaneously. There can be people who are, at least potentially, "willing to serve" (or cooperate). There can exist a *job* which requires the cooperative efforts of people, yet without effective means and methods of *communication*, the ingredients are useless. The ingredients of "willingness to serve" and "common purpose" will *never* be brought together so that a product will result.

Let me name the three individual ingredients of organization again—1. common purpose, 2. willingness to serve, and 3. communication.

Common Purpose

Common purpose, or objective, or a product of cooperation, or a prospective result must be known and agreed upon by enough people to perform the necessary acts. In other words, "just what kind of a pie you're going to make" has to be known before anyone will decide to cooperate. The product, or objective, must be one which is acceptable to the people concerned.

The "willingness-to-cooperate" ingredient has many aspects to it. In the first place, it must occur almost simultaneously with the objective becoming known. On the part of each individual there will be a comparison of the incentives (or advantages to him) to cooperate here, someplace else, or not at all.

When the common purpose, or objective, has become known to those potential cooperators through the medium of communication, *additional* communication must take place in order to achieve coordination of the acts of these people in relation to the attainment of their objective. Example: Your job is to cook the hamburgers; your job is to transport them to the consumer; and your job is to wash plates and glasses.

Willingness to Serve

The term "coordination" is one which is probably overused in our various conversations. Dean M. R. Lohmann and Professor H. G. Thuesen of Oklahoma A. & M. College, who are outstanding thinkers in this field, think of *coordination* as *the contributing of personal acts to an organization that are appropriate as to time, place, and manner so as to augment the acts of others in the achievement of an end*.

* Based upon a presentation to the Industrial Engineering Conference at Michigan State University, September 14, 1956.

Cooperation (or willingness to serve) is the forerunner of coordination. But no matter how willing people may be to coordinate their acts, willingness alone will not achieve the end which they are seeking. The acts of one person in relation to another must be fitting as to time, place, kind and manner.

Communication

Preceding these coordinative actions of a manager (or the coordinative communications) is the activity which we commonly call *planning*. This is really the *preparation* for managing. When a man is planning, he is forecasting. He is visualizing the changes which he feels necessary to attain the objective. He is visualizing the acts needed to accomplish the objective. He is visualizing the sequence in which these acts must be performed, and he is forming a "before and after" mental picture of the job to be performed, and the results. The planner has to take into consideration at all times that the ultimate goal in organization is the net satisfaction of everyone that has anything to do with the organization. By "net satisfaction" I mean that the benefits of the situation equal or outweigh the burdens. It may sound somewhat academic to you at first thought, but I think that if you will consider the fact that unless the employees are satisfied with their product, with there incentive, with their conditions of work in comparison to what they could do someplace else, then you will have no employees. If the active managers themselves do not receive some sense of satisfaction, then turnover of management employees may occur. So there must be net satisfaction on the part of all concerned or the process breaks down.

If the Industrial Engineer is to be the "professional engineer who helps managers manage" he must have this objective concept of the activity of managing. To fulfill his normal staff duties with imagination and success he must have this management-as-a-whole viewpoint.

Industrial Engineering Functions

I just mentioned the term "staff duties". Most people will agree that the function of the staff personnel is to *aid* the "line" personnel in performing their work. Then, practically all industrial engineering functions are staff functions.

Consultative functions are those which (study, measure, analyze, recommend) furnish aid in the performance of an activity. The only difference being that staff is restricted to aiding *line* operators, while the other, *any* operations. Then, truly, industrial engineering functions are consultative throughout (because we don't necessarily restrict ourselves to aiding "line" personnel).

But to conform with the more common concept of consultative services it might be well to set aside the fairly widespread functions performed by the Industrial Engineering Department and take a look at how the Industrial Engineer with his company-wide experience, his knowledge of costs, his ability to get along with people and his engineering knowledge can and should be utilized in an organization.

I am in an ideal position to practice this type of activity—teaching the techniques of methods improvement, motion and time study, tool engineering plant layout, etc., and spending my spare time consulting, largely in the fields of organization planning, executive development, job evaluation, general management and personnel problems and methods study. I try to limit the methods studies to areas which have not been explored, or at least, have had very little exploration done in them. An example of the latter is some work I did three years ago in studying the tearing down and rigging-up of portable oil rigs in the Southwest and in Canada. This was written up in a series of three articles in the *Petroleum Engineer* magazine.

What are the areas where the Industrial Engineer (whom I have described) could be used? In describing my own activities I have mentioned some, but let's list a few: Job Evaluation, Operations Research, Management Development, Data Processing, Planning Major or Minor Moves of Physical Equipment, "Master Planning", Problems Encompassing the Coordination and Analysis of Information from Several Departments, Human Relations, Management Strategy, and Organization Planning.

Wage and Salary Administration

Let us get more specific and consider several of these and how the Industrial Engineer could be utilized. Take the function of Wage and Salary Administration. The responsibility for it may rest with the Controller Department, Employee Relations Department, Industrial Engineering Department, the Departmental Manager or no one. Let me cite a current example.

A major company, financially successful and with the reputation of being a well-organized firm, up until a year ago had a wage and salary administration somewhat as follows: Salary and operating budgets were formulated and passed "up the line" until it reached the top three men in the company. A period of time elapsed and then the *real* budgets were "passed down the line" (without discussion, explanation or resemblance to the ones originally submitted). These same three men would periodically review *every* recommended salary raise in the company. In size, this is one of the top twenty oil companies in the United States, so this meant a lot of recommended salary changes. It also meant that the salaries in the company were based on—I'm not sure what. The company's salaried personnel turnover was about 18 to 22% and in some departments much higher.

The Industrial Engineer is a "natural" for consulting on this problem. He is interested in reducing costs, and this labor turnover was costing the company plenty of money. The Industrial Engineer is interested in people getting paid in close relation to the difficulty of the job and the individual's proficiency. The company was failing in this respect too. The Industrial Engineer is trained to "break

a job down into its component parts" and writing an operative description of the job. The first item of work in the technique of Job Evaluation is the writing of good consistent descriptions with a different slant from his operative descriptions, but the same analytical ability is required. I would suggest that he not be asked to write all the descriptions, but that he be given the job of training a committee of operating people to do so. Next, he is a "natural" for *training* and *advising* the evaluation or policy group. Here some ability with figures is needed, but of greater importance is the ability to "look at the job and its requirements" not who is on the job—in other words, to retain an objective viewpoint.

He is accustomed to presenting facts with numbers and graphs. This he does (in Job Evaluation) when the company's wage practices are compared to other company's. He is also accustomed to presenting alternative methods and solutions for the decision of a line executive. This he will do when the study has been completed and recommendations formulated.

Thus, by following this plan the wage earners, whose jobs have been studied, have had them evaluated, not by an Industrial Engineer, but by the people who knew the jobs intimately. The Industrial Engineer has been the teacher and consultant. He may *help* formulate the general salary administration policies, being the individual who visualizes the problems which may arise and methods to solve them. Again he's acting as a consultant and, by so doing, the company is using the Industrial Engineer's natural and cultivated abilities.

Operations Research

The Industrial Engineer with the management-as-a-whole concept is the logical person to participate in, or lead, an Operations Research analysis. Many firms may have problems which are receptive to the so-called Operations Research mixed-discipline-group-attack, but do not feel that a permanent group is necessary or economical. The Industrial Engineer can guide a selected group in obtaining problem solving methods, educate the personnel who will use these methods and return to his regular work. Thus, another area of internal consulting is developing.

Personnel

I have found that the Industrial Engineers do a good job of "sizing up" the abilities and personal requirements of management personnel. They have to work with the managers and supervisors in activities that exercise their management ability. They are in a good position to observe the management development requirements of these supervisory people. If the Industrial Engineer attempts to maintain an objective viewpoint of the people with whom he must work, he is a most valuable consultant as to what to do to enhance the management ability of the various personnel.

Planning Plant Layout and Plant Moves

I recently talked with a manager of a plant whose machinery and equipment were moved from one building to another, some five blocks away. In my own experience the Industrial Engineering Department would be called upon to lay out the floor plan in the new building (in close cooperation with the "using" department heads). But this would have been the limit of our work. The manager asked his Industrial Engineers to *plan the move* so that he could start operating again as soon as possible. (They also made a new layout of equipment). He stated that he overruled the recommended moving procedure in one or two instances and also the layout placement of machinery in one or two instances. This manager thought it was a highly successful move, except that he should *not* have changed the recommended procedures at all. Those changes he made were their only mistakes. Again, this was not a continuing job, but rather one that happens occasionally. Then use the best equipped man as a consultant.

Planning

I once was chairman of what we called the "Master Planning Committee" for a plant. This committee, besides me, was composed of the Chief Engineer, the General Sales Manager, the Assistant Plant Superintendent and the Controller. Our job was to dream into the future. We were supposed to have fantastic dreams as well as dreams based on educated guesses. This dreaming was to be about what the plant would be like 5, 15, and 25 years from now. Our planning was to include entirely unconventional methods of operation. It was to include methods, never tried before, of smoothing out seasonal fluctuations. Each one of the members of the committee had dreams about his specialty in relation to the situation under current discussion. The Sales Manager, after consultations with his people, submitted his ideas of "what, where and how much" in relation to the marketing situation 5, 15, and 25 years from now. We then planned the changes and additions necessary to accomplish his forecast.

As the chairman and Industrial Engineer I gathered the material, questioned it, analyzed it, and put it into words, drawings, and costs. Then whenever a proposed change was being considered, my report and I were consulted to see just how the immediate proposal fitted in with our long range planning. Here, again, the Industrial Engineer was being used on a project that required the committee to meet two hours per week and took probably another six hours of my time per week. This was another consulting function within the company.

Human Relations

How many of you have learned of a new policy that's going to be put in effect by top management, and have said, "Why in the world are they doing that now? The idea is okay, but this is the wrong time". Most Industrial Engineers are in close tune to the morale and probable human reactions in the plant. You know that *timing* in

management is important (and I'm not talking about timestudy here). A company I consult with installed a suggestion box plan about a year and a half ago. It was put in on the spur-of-the-moment with cost savings suggestions beings its principal objective. Their suggestion boxes were works of art, costing about $15 each, but the mechanics of the plan were not properly thought out. The reviewing committee met regularly at first, but later postponed more meetings than it actually held. At any rate, at the time that the president of the company asked me what should be done with the plan, no suggestions had been received during the immediate past 5 months. I presented him with several alternatives, the principal one being to abandon the plan. He was convinced, and proceeded to compose a letter announcing the abandonment. This action, as you probably have surmised, would only have called attention to the fact that here was something that the rank and file did have that was now being taken from them. (The fact that they had not used this plan would be irrelevant in their minds). The timing was wrong, and the strategy was wrong. The Industrial Engineers are well equipped to discern such situations and aid in their solutions. In this particular case the president was advised to put one man in charge of the program, rather than a committee. He was not to promote it, but was to receive any suggestions, get them evaluated by line personnel and make awards when justified. If the plan revived itself, fine; if it continued to die, then management could not be accused of arbitrary actions.

If you have the concept of management I have outlined, you are an excellent person with whom to consult on human reactions and management strategy. Top managers need someone to talk to, someone who can aid in the analysis of a problem and who has no "axe to grind" which would affect this advice.

Basic objectives

We talk a lot about the necessity of the young engineer, and particularly the Industrial Engineer, needing to have a "questioning attitude". This is just as true in relation to obtaining more effective operations through management and organization planning, as it is in methods improvement work. In any analytical study one of the first considerations must be, "What are we trying to do?" This is related to the formerly mentioned organization ingredient "common purpose". I have been consulted about many management problems which have seemed to completely stump the very capable people in the company, and appeared to me to be very difficult problems to solve. Invariably, these managers, who were formerly stumped as to what should be done, began to solve their own problems when encouraged to answer my question, "What is the objective?" or "What are we really trying to do in this particular case?" Answering that question is more difficult than it sounds (in many cases) since we very seldom discipline our own selves to the point where we have thought through this innocent appearing question.

Isn't this the question you always ask when you are introduced to a new machine or process, or are changing the machine layout, etc.? The same principle applies to management and organization planning what are we trying to do? Top managers should use this man, the Industrial Engineer, who is so accustomed to asking this question in his own work that he will use the same approach in other problems.

After the objective has been agreed upon, other considerations can be taken up. Going back to the three principal ingredients of an organization you will recall that the ingredient "communication" was stressed. If there is any one of these essentials of organization which is more important than the other, or which is a possible cause of effective or ineffective operations more than any other, it is probably that of communication. *A poor method effectively communicated will normally produce better results than a good method poorly communicated.* Poor communication in an organization shows up in many different ways. Sometimes the condition makes itself known directly and, other times, only by analysis does the real trouble appear.

Let me outline a danger point in one company. The President has personally employed four or five top chemical engineers in the last four years. These fellows were employed on the basis that, as the company grows they will be needed and will be at hand. In the meantime they are to conduct investigations for the President or work wherever the plant manager assigns them. Now both the plant manager and these "super-numeraries" are headed for some kind of difficulties due to awkward relationships. These situations seem to be quickly seen by an Industrial Engineer of the type we are considering here.

Quite often there seems to be no relation to the difficulty being confronted in organization or in operations to that of communication. Let me illustrate by using another case history. The Executive Committee of the Board of Directors of a very small corporation came to me a few years ago and asked for help in straightening out difficulties in their *production line*. Their operations included aluminum die-casting, production machining, and assembling small submersible pumps which were sold through jobbers. Records showed that they were receiving approximately 20% of the product sold back into the plant as being non-operative within the guarantee period. The organization had from 25 to 75 people employed, according to the season of the year. It had been operating at a net loss of between $15,000 and $30,000 per year for the preceding 5 years. In fact, the preceding year the company had operated at a net loss of $25,000. The Executive Committee, themselves, were quite sure that the difficulties lay in either the design of the product or in sloppy methods of assembly.

We toured the plant and several significant errors in assembly methods could be observed. These could have been corrected without too much difficulty and cost to the company. The superficial look at a company and the

application of a remedy here and there is as dangerous as the local treatment of a boil that may be only the outward manifestation of a much greater organic disturbance. Likewise, in this situation it was felt that a closer examination was needed. I asked the Committee for time to make further observations and then I would come up with some recommendations for future study. They were desperate, I guess, and gave me complete freedom to study anything anywhere. About one week was spent in talking with various employees.

Various personnel were interviewed on how they thought the company was organized and how it operated; what they recommended; what were their principal gripes in relation to their own job; and what were their most common problems.

Numerous interesting facts were uncovered, but the most important was the information given by charting the organization as the three top people at the plant saw it. These three men saw and talked with each other several times a day, every day and yet their conception of their organization was different.

Analysis of the management and its organization (or communication system) brought the basic difficulty to light. No amount of localized "first aid" out in the plant would have cured the problem brought about by the misunderstanding as to the responsibility and authority for the various functions of the business.

Written descriptions of areas of responsibility were made and explained to each of the top supervisors and executives.

More detailed surveys and investigations followed. The method of financing the company was found to be very shortsighted. An analysis of costs, prices, and production capacity was made and a break-even chart based on the major item (it also being the least profitable) was made. The two-year guarantee was cut to one year, and materials handling was improved.

It was found that there was no inspection of motors before they were assembled in the sealed box. Inspection procedures were written. (Over 10% of motors were inoperable on receipt at the factory.)

The real point is here is another area in which the Industrial Engineer should be consulted. There are a very few companies which have departments of organization. So this is not the function that requires permanent personnel, but rather one which is very conducive to a consultative type of fulfillment.

Summary

By only touching on the normal duties of the Industrial Engineer I do not mean to "play-down" their importance. There must be a continuing effective program of methods study, work measurement and cost control. Established Industrial Engineering Control Systems continue to give valuable information for tactical day-to-day decisions. I want the Industrial Engineer to be given more non-routine problems to analyze. Industrial Engineering is increasingly of more help to management in the strategic decisions. Operations Research with its objective of furnishing aid in decision-making is being significantly staffed by I. E.'s.

I had a boss once that every time he was about to give me another unpleasant assignment would preface it with, "Now Wilson, this offers you a big challenge". The association of that term became rather distasteful to me.

I'm sure you have encountered this same phrase. Challenge and response is a familiar pattern. Individual and social development are interpreted in these terms. A challenge is presented by the environment. To meet the challenger, the individual and his group must develop.

Industrial Engineering is so challenged today. The accelerating changes in our industrial environment demand that we develop in understanding and capacity, in attitude and method.

I want Industrial Engineers to be known as "those professional engineers who help managers manage". We must not get in a rut and think only in terms of techniques. If you can think in terms of the "whole"; if you can think of management as "the activity of maintaining the system of coordination of human activities known as an organization"; if you can analyze an organizational situation in terms of its three ingredients: 1. common purpose, 2. willingness to serve, 3. communication; and consequently aid in making decisions on top levels (as well as apply the techniques too), *then* executives will *seek you* out to perform these internal consulting functions I have described.

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Cost Control through Timestudy

By Phil Carroll*

Professional Engineer, Northeast Region Vice President AIIE 1956-57

Frank Gilbreth said, "Scientific Management hangs upon the science of timestudy." Yet, few of us would argue that the garden variety of timestudy we see in many plants even faintly resembles a science. Many men limit their "timestudy" to a few watch readings of an operation cycle. Some do not sub-divide the cycles they observe into their basic elements. Others direct all their efforts toward "rate setting". Apparently, they think that the main purpose of timestudy is to provide a way to pay people more money for more production.

I think it is the best way to measure a fair day's work. With work standards and incentives that are used properly, you do get more production. You do increase earnings. Besides, you do attain lower costs. Timestudy with incentives is the only management "tool" I know of that will help to bring about all three of these constructive results.

What Is Cost?

But I think there is more to timestudy. My way of looking at it might be made more clear if we expressed the term as the study of time. When we study time more carefully, we can gain additional benefits that are often more far reaching.

To attain the ends I have in mind, let's consider the study of time as a sorting process. By timestudy, we should sort time and work done into several parts. One represents productive effort. The others are extra costs.

In manufacturing, we have another special division—one that represents good, salable pieces. Salable pieces are those our customers buy. Products that go out the door and stay out are the only ones that can earn overhead.

Thus, when we talk about cost control, we should decide first what we mean when we say cost. The costs in manufacturing that timestudy can affect are two. We call these direct labor and overhead. These two are interrelated. In most plants, the overhead is applied to the direct labor as a percentage.

The first interrelation I want to point out is in the way we determine the overhead per cent. To compute this per cent we divide the so-called overhead by the so-called direct labor. Thus, the timestudy man can alter the per cent of overhead depending upon how he classifies time spent and work done by those we call direct labor. This is an important point as you can see. The timestudy man will cause a change in apparent cost when he changes or goes along with a change in work or time classification. Here is the place where I believe that timestudy has a direct bearing upon cost control.

Therefore, to gain cost control through timestudy, we should look beyond the too common practice of "rate setting." We should utilize timestudy to set up the foundation for better management. In this instance, we're talking about the better management of costs. This calls for a better knowledge of costs and, I think, better costs.

Management Errors

Starting from that point, I suggest that the timestudy man is the one who sets the equivalent of good salable pieces depending upon what he calls direct or productive labor. He is the one who sets the "rate". Afterwards, the accountant builds the cost he gives to management on the foundation set by the timestudy man. Are the costs correct?

Many costs are not worth the paper they are written on. To me this seems tragic. My concern is that managers are making decisions every day that begin with incorrect "facts." Let me see if I can show you where some of the errors lie.

Let's start with a fundamental that some of us appear to overlook. It was well stated years ago by Henry L. Gantt. He said, "In connection with the man's record, it is the most complete analysis we can make of the working of a plant, and the one that will help us most quickly to bring into their proper channels things that have gone haphazard."

If we look with this sharpened point of view at almost any operation we see that our so-called direct labor divides itself into several groups. One part is direct. Another part is indirect. A third portion is waiting time.

Time and work go on every day that do not result in salable production. These are added costs. These extra costs should be separated from the true direct labor because they do not represent added production. They cannot

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earn overhead no matter what the figures may indicate. I call these extras "Management errors." I divide them into three groups—failure to plan, failure to specify, and failure to follow up.

Failure to Plan

Perhaps the most common illustration of "failure to plan" is waiting time. All of us recognize this one. We all talk about having the foreman "get the next job ready". But there are many other examples of waiting time. Here, we are interested in those the timestudy man may or may not see.

Take one example. In 1952, I was looking at a group operation where seven men performed several operations in sequence. In effect, they handed large pieces from one to the next. After awhile, I asked the timestudy man how he set the standard time. He pointed to one operation and said, "I set the time on the bottleneck operation and multiply by seven."

Many "rate setters" follow that practice. They bury the waiting time caused by unbalanced work loads in their "rates". In so doing, they say, in effect, that waiting time is direct labor. Also, they start a chain of events that puts the waiting time into inventory and eventually into the "cost of sales".

Buried Waiting Time

In this sequence, overhead is applied to the waiting time. To make an example, suppose you have $300,000 of overhead. With this is a volume of 100,000 standard hours of production. From these, we compute an overhead rate of $3.00 per hour.

Next, assume you have two major products—motors and pumps. In setting the standards for motors, suppose you have buried 5 per cent of this kind of waiting time. In those set for pump manufacture, there was included 20 per cent hidden waiting time. To carry on our example, suppose that in the month of June you have 30,000 standard hours of motor and 70,000 standard hours of pump production. Incidentally, I use units (standard minutes) in everyday practice rather than standard hours.

Regardless of terms, for the month of June, your accountant would apply $4,500 of overhead to the 5 per cent waiting time buried in the motor production standards. To 70,000 standard hours of pump production that include 20 per cent waiting time, he would apply $42,000 of overhead. The total overhead applied to waiting time for June would be $46,500. This is an average of $.465 per hour for the 100,000 standard hours turned out in June.

	June	
Motors	30,000 × .05 × $3.00 =	$4,500
Pumps	70,000 × .20 × $3.00 =	$42,000
	100,000	$46,500 Ave. $.465

To make this point more vivid, let us suppose that we have the same total production of 100,000 hours in the month of July. But let us assume that our customers have changed their choice of demands. They order 70,000 hours of motor production in July. Thus, to the 5 per cent buried waiting time in this production, your accountant would apply $10,500 of overhead. To the 30,000 hours of pumps ordered in July that include 20 per cent waiting time, he would apply $18,000 of overhead. The total applied to waiting time for the month would be $28,500. The average would be $.285.

Volume Measure

Notice, our "volume" of production appears to be the same in both June and July. Is it? Here is one mistake we make that misleads management. And, as you can see, we distort costs in two ways. First, we make it appear that our overhead rate is lower than it is. Second, we cause overhead to be applied incorrectly.

We would contribute much more toward cost control by reporting the waiting time separately. It should not be buried in the so-called standard minutes or standard hours of production. Were this done, the reports for June would show 15,500 hours of waiting time. That would amount to over 18 per cent of the actual production of 84,500 salable standard hours. Tell me, would your manager be content very long with a reported waiting time of 18 per cent?

Now let's take the next step—the effect on your overhead rate. If you report waiting time, usually it is charged to overhead. Then, if for simplicity, we say your wage rate is $2.00 per hour, the cost of the waiting time in this case would be $31,000 added to overhead. Thus, your total overhead becomes $331,000. The overhead rate then is $3.92 per standard hour.

As a result, we would change the apparent costs of our products. For example, in the original costing, the accountant would have charged $210,000 of overhead to the pumps. In reality, it should have been nearer $220,000—an increase of 4½ per cent. Contrast those figures with the overheads to be charged to motors. Under the original assumption, the accountant would have charged $90,000 of overhead to motors. More correctly, he should have charged about $112,000. That is an increase of 24 per cent.

You might object to these rearrangements saying that the overhead of waiting time should be applied to the products that cause it. That is correct. In the same way, so should the other overhead costs averaged in the single rate used in this example. However, here I'm trying to show only that (a) we miss an opportunity to improve cost control by burying waiting time in our standards.

At the same time, (b) we cause the overhead expenses such as postage stamps and vice presidents to be misapplied in our product costing. As a result, we are a party to causing errors in management decisions. These may be in either direction. The manager may decide not to go after certain business because there does not appear to be any profit possibilities in selling the product in question. In contrast, he may put on a drive to get more volume of a

product that appears to be a money maker. You can think of many more similar decisions that can stem from erroneous costs.

Failure to Specify

Now, let me further emphasize the value of better timestudy with another example. This one is a gold mine of cost control that some timestudy men step right over. It lies in the extra costs that I group under the term "failure to specify". You may look for it any place where timestudy men set "temporary rates".

Usually the condition that calls for the use of the term "temporary" is one requiring some extra work. Perhaps the material is too long or too short, too hard or too soft, too thick or too thin. In many such instances, we use the label "temporary" to indicate that conditions are not as they should be.

For instance, let's use some arithmetic to show what happens when we set "temporary rates". Suppose we have a normal production of 40,000 standard hours with an overhead of $200,000. Most plants would divide one by the other and arrive at an overhead rate of $5.00 an hour.

Next, imagine that we have a sudden rash of "bad casting". To maintain incentive coverage, we rush out on the floor and set "temporary rates". In total, we add 10,000 hours. Seemingly, we now have a production of 50,000 standard hours. It follows that by usual methods of computing, our overhead rate becomes $4.00 an hour.

Perhaps your manager would be pleased. His overhead rate has dropped from $5.00 to $4.00 per hour. Now I ask you, "Is that fact or fiction?" Actually, the 10,000 added hours represent extra cost rather than extra production. The salable production remains as 40,000 standard hours.

To reflect what has actually taken place, we should have added the cost of the 10,000 hours to our overhead. Again, let's use $2.00 per hour to keep the arithmetic simple. Then, our 10,000 hours become $20,000 added to make the total overhead $220,000. Our new and more correct overhead rate becomes $5.50 per standard hour.

Control Is Action

The 10,000 hours separated from direct labor would surely get the attention of most managers. So would the $20,000 added to overhead. The increase in overhead rate to $5.50 certainly would. In any event, chances are that management would take action to reduce the excess cost caused by the bad castings. Thus, timestudy would help to improve cost control.

Now let's bring out another twist of this same "temporary rate" fallacy as it applies to an everyday problem. Most plants have "slow machines". These are the machines that are older than the "new" ones bought 15 years ago. But they have different rates of output. Commonly, we set "permanent rates" for work done on the better machines. Usually, we set "temporary rates" for operations done on the "slow machine".

To make the point, let's look back to our previous arithmetic. Suppose the 10,000 extra hours were added because the production was run on the "slow machine". Then, in the usual "rate setting" procedure, we would make it appear as though we got out 20 per cent more production. Using standard or previously computed overhead rates, our accountants would report over absorbed burden for the period.

And there is another mistake. Companies are charging a part of the higher depreciation of the new machine to the work done on the slow machine. In contrast, I think of the extra 10,000 hours caused by using the "slow machine" as a depreciation cost spent as labor. Maybe it is the cheaper of the two costs. We know, however, that if we showed this 10,000 extra hours separately, someone would soon find out. Again, we have used timestudy to improve cost control.

Failure to Follow Up

Similar to the foregoing is another type of measurement that I think important. It occurs most often perhaps as a result of methods improvement.

We are always finding better ways to turn out production. We "tool up" whenever we think the quantity is large enough. Consequently, we have better methods on some operations than on others. Our better methods may be the timestudy standards we set on some operations but not on others. Perhaps we set standards in some departments but not in others. In some instances, we may have production control in some departments but not in others. Any of these differences may be illustrated by the following arithmetic.

Let's suppose we have a plant with overhead of $200,000 and a direct labor cost of $100,000. Customarily, the accountants would divide the overhead by the labor and arrive at a 200 per cent overhead rate.

To show the error I want to portray, let's divide our overhead and labor into two groups. These might be indicative of two departments or two products that have the two different degrees of "management tools".

$$\frac{\text{Overhead}}{\text{Labor}} \quad \frac{\$100{,}000 + \$100{,}000}{\$50{,}000 + \$50{,}000} = 200 \text{ Per Cent OH}$$

Now we are ready to improve the management methods used in one of the departments or on one of the products. Let's add $11,000 to the overhead for one. It was a profitable venture because we reduce the so-called direct labor by $20,000. Our fraction now takes this form

$$\frac{\text{Overhead}}{\text{Labor}} \quad \frac{\$100{,}000 + \$111{,}000}{\$50{,}000 + \$30{,}000} = \text{?} \text{ Per Cent OH}$$

What is our new overhead per cent?

You may stop to think. Most people jump to conclusions and say 264 per cent. ($211,000/$80,000). In most cost departments, that is the rate that would be used. The reason is that all of the overhead is collected in one pile and all of the labor dollars in another.

Methods Improvement

If you look more closely, you will see that the overhead per cent for the department or product methods not changed is the same as it was before. It remains at 200 per cent. But the overhead per cent where the improvements were made is now 370 per cent.

As previously pointed out, to average is wrong. To disregard these differences and use an average overhead per cent will incorrectly apply the costs of the improvements to the operations that were not improved. Here is another form of the kind of time separation we can get through timestudy.

You may be able to see this more clearly if you prefer to think in terms of "permanent" and "temporary" standards. The difference between these two methods of production is an extra cost. The extra is spent in the form of labor because we think it is less costly in the aggregate than the cost to improve the condition. For instance, the change here may have been brought about by making tools for the larger quantity runs. The smaller runs are still made by the old methods. The word old as used here in no way implies criticism. Under the new circumstances, however, the money we did not spend for better "management tools" is no longer direct labor. When compared with the "new direct labor", it is tool making cost spent in a production department as the cheaper way.

You may think of the new standards set with improved tooling as "permanent". From that viewpoint, the standards that apply to the now "old method" may be thought of as "temporary". The difference is tool cost—indirect labor of $20,000. This amount does not represent extra production. Instead, it is higher cost.

Error of Averages

We make these and similar mistakes because we treat one standard minute or standard hour like another. Managers do the same thing when they treat one sales dollar as though it were the same as another. Accountants make the same errors by considering one overhead dollar should be applied the same way as another.

Better Timestudy

We can help to correct some of these mistakes by improving our methods of timestudy. We should set standards that represent good, salable output. We should think of one standard minute as representing one piece of product on the shelf ready to deliver to the customer. Then 1000 standard minutes should represent 1000 pieces on the shelf. If every 1000 standard minutes you set up by timestudy represents 1000 salable pieces you have a common denominator. You have a measure of salable output. Every other kind of work or waiting that may be done to get out production represents extra cost—not extra production. These extras should be separated from our measures of so-called direct labor. They are "management errors". They cannot earn overhead. They are overhead.

When we see how much these cost us we are in a position to decide whether or not it is economical to make improvements. We can weigh the costs to reduce them against the costs to live with them. My belief is that many of these extra costs would be reduced rather quickly if we knew how much they were now costing us.

From the standpoint of cost control, the separation of these extra costs is important. I have tried to show this in two ways. First is the mistake the timestudy man makes in mixing horses and apples. Too many treat one kind of standard time minutes like another.

Better Cost Control

Timestudy would greatly assist cost control if timestudy men would make the distinction between standard times representing salable production and all others. In this way, every extra cost would be sorted out and reported. This is the starting point of management action to control costs. In other instances we say the first step in solving a problem is to get all the facts.

Secondly, they would help to avoid piling one mistake on top of another. The mistakes we make in setting standards are multiplied by 3, 4, or 5 depending upon how large the overhead ratio is. Thus, our errors are exaggerated. That is not the important point. What really matters is that management is misinformed about the costs of the several products turned out. As a result, the relation of cost to selling price is thrown off. The actual spreads may be greater or less than the profit margins indicate.

Working from indicated profit margins, your manager may decide to put on a sales campaign. Everybody may be pleased with the increased volume. But they may be surprised to find that the profits for the period went down instead of up.

Management's efforts to make correct decisions are difficult enough. We should not make their problems more complex by faulty timestudy. We should use the tools available to us to establish standards that actually measure salable output. We should sort out all the extra costs that are made necessary by the current methods of production. We should make more of an effort to provide management with at least the basic facts of costs. In so doing, we will greatly improve the opportunities for cost control through the better use of better timestudy.

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Allowing in Time Standards for Weight Handled

By M. E. Mundel

Professor of Management and Vice Director, Management Center, Marquette University, Milwaukee, Wisconsin

In any system of direct time study, cognizance must be taken of the weight handled by the worker (or force exerted on levers) in performing the job for which the standard is being determined. In subjective rating procedures an adjustment is usually made in "the mental concept of normal" to which the performance of the operation being observed is compared although an additional correction frequently is made in the form of a fatigue allowance (1). In objective rating (2) the pace exhibited by the worker is compared to a fixed or standardized concept of normal performance, without any attention being given, during rating, to the difficulty of the job. The difficulty of the job is adjusted for subsequently by a correction factor taken from a table which gives percentage additions for various "objective" conditions tending to make the so-called "normal pace" not equally attainable in a specific job as compared to the "no difficulty" condition used to develop the standard pace used for rating.

Whatever system is used, one needs to know the effect the weight handled or force exerted will have upon the time to perform the work. Apparently conflicting data appear in the literature but, as will be shown, these may be correlated if the correct variables are used.

Previous Data

Maass (3) experimented with ten college students. His task consisted of moving, as fast as possible, a weighted box 18 inches across a table followed by an unloaded movement of the hand 18 inches to the point of origin, a free movement back to the box, a movement of the box etc., as fast as the operators were able to move. The operators worked roughly half of the experimental period.

A study by Solberg (4) used ten college students, (all recently released U. S. Marines) to move, at their maximum pace, a loaded lever up and down for 5-minute work spells with 5-minute rest periods between each work spell. The load on the lever was varied from 0.5 pounds to 50.5 pounds with only one value being used for each 5-minute work spell. Solberg recorded the time-per-cycle for the last minute of each work spell. The subjects worked from low to high weight on one day and from high weight to low weight on another day to minimize the effect of order presentation.

Sekerci (5) used ten college students to lift a bar to which weights were attached. The weights used varied from 2 pounds to 44 pounds in 7 pound increments. A mechanism returned the bar to the original position (9 inches from the ground) so that lifts to 33 inches, and free movements back, could be made. Sekerci used two-minute work spells, with the subjects working at their maximum pace with two-minute rests in between each work-spell, random orders of work for each subject, and two lifting conditions, (a) with arms and trunk, and (b) with legs (by squatting and standing).

Fig. 1 Worker Lifting Boxes (Lehman and Kolaree)

New Data

In order to relate these data with industrial practice, and in an attempt to determine the reason for the apparent differences, two additional experiments were undertaken. With the cooperation of Cudahy Brothers' Co.,[1] a Milwaukee concern with an extensive shipping department, a test situation was constructed. The situation required the workers to stand in one spot and lift cartons ($7\frac{1}{2}$ inches x $13\frac{1}{4}$ inches x $20\frac{1}{4}$ inches) 18 inches up and at the same time move them 2 feet to the left and deposit them on a conveyor which returned them eventually to the operator, but spaced so as to permit free lifting.

The initial position of the carton was 9 inches from the floor and the surface of the conveyor on which they were deposited was 27 inches from the floor. The weight of the cartons varied from 2 pounds to 80 pounds in algebraic steps although all of the cartons being handled during any one run were of equal weight. Figure 1 shows a worker on the job.

TABLE I

Data from Weight Experiments

Pounds Pull on Lever or Weight per Lift	Solberg; Time per Cycle in 00001 Min.	Maass; Time per Cycle in Minutes	Sekerci leg; Relative* Time per Lift	Sekerci arm; Relative* Time per Lift	Lehman; Time per Cycle in Minutes	Kolarec; Boxes Lifted per Min.
0.5	20.0					
1.0					.0186	45
2.0			150	136	.0188	47
2.5					.0186	48
3.0	22.0					
4.0		.130				
5.0					.0190	46
5.5	24.0					
8.0	25.0				.0200	44
9.0			157	146		
10.13		.137				
10.5	26.4					
12.0					.0212	42
13.0	27.2					
16.0			165	158		
16.25		.144				
18.0	28.6					
23.0			174	173		
23.13		.156				
24.0					.0226	37
25.5	29.0					
30.0			184	191		
37.0			196	212		
38.0	31.4					
44.0			208	239		
48.0					.0266	25
50.5	33.6					
80.0					.0300	16

* In Sekerci original report these data were in cycles per work spell but access to the original values could not be obtained inasmuch as the thesis was unobtainable.

[1] Special thanks are due to C. J. Allen, Chief Industrial Engineer, who made the experimental facilities and workers available.

In the first experiment by Lehman (6) the ten operators, all of whom normally did work of this type, moved 5 boxes from the lower platform to the conveyor, as rapidly as possible, followed by a two-minute rest. The time to lift the 5 boxes was recorded.

This procedure was used starting with the lightest box and proceeding up through the heavier boxes. The operators then repeated the work at each weight starting with the heaviest box and proceeding through to the lightest. The weights used in pounds were 1, 2, 2.5, 5, 8, 12, 24, 48, 80. During the experiment, the operators worked a total of approximately 2 minutes out of 38 minutes or 5.3 per cent of the time. The operators were given a strong incentive to work at their maximum pace by paid time-off following the experimental run.

In a subsequent experiment by Kolarec (7) the same apparatus and boxes were used but instead of the 5-box sequence, each of five workers lifted the boxes for 5 minutes followed by a 5-minute rest. During the first work period of 5 minutes, the workers worked with the 1-pound boxes, and progressed by work spells to the 80-pound

TABLE II

Data from Table I Converted to Total Pounds Lifted per Unit of Time by Selecting for Each Experiment a Time Value so as to Permit Plotting on a Similar Scale*

Pounds per Pull on Lever or per Lift	Solberg; (per .02 min)	Maass; (per 20 min)	Sekerci leg; per 25000 Time Units	Sekerci arm; per 25000 Time Units	Lehman; per 2.5 Minutes	Kolarec; per 2.5 Minutes
0.5	50					
1.0					134	112.5
2.0			333	368	266	235
2.5					336	300
3.0	272					
4.0		615				
5.0					658	575
5.5	458					
8.0	640				1000	880
9.0			1430	1540		
10.13		1480				
10.5	795					
12.0					1415	1260
13.0	956					
16.0			2420	2530		
16.25		2260				
18.0	1260					
23.0		3300	3320			
23.13		2840				
24.0					2560	2220
25.5	1790					
30.0			4070	3930		
37.0			4720	4360		
38.0	2440					
44.0			5290	4600		
48.0					4500	3000
50.5	3000					
80.0					6660	3200

* Various time periods chosen so as to make slope comparisons readily feasible on a log log presentation.

boxes; then repeated the five-minute work, five-minute rest pattern, going from the 80-pound to the 1-pound boxes. The workers were induced to work at their maximum pace during the three-hour experimental period by giving them the rest of the day off with full pay. All of the workers studied were accustomed to handling, loading and lifting boxes, such as were used, as a normal part of their usual job. The number of boxes handled each minute at each weight was recorded.

Table I gives the data for each of these two and the previously referred to experiments in a form similar to their initial reporting. In Table II the data has been converted to pounds lifted or overcome per period of time using a time value in each case such as to permit charting on one scale.

These data from Table II were plotted using a log-log grid as in Figure 2.

Discussion

All of the data exhibit an exceedingly similar slope pattern with a few exceptions. First, Solberg's is slightly flatter than the others but it should be recalled that he recorded only the last minute of a five-minute work spell, which may well have tended to maximize the work decrement created by the effort of lifting each weight. Secondly, Lehman's curve does not fall off at the higher weights as do both Sekerci's two curves, Kolarec's curve and Maass' curve. Thirdly, Sekerci's "leg" curve does not appear to fall off as greatly as the other three. It should be noted that Lehman's experiment did not require the workers to work as great a proportion of the time as the other experiments. Also, Sekerci's leg experiment involved a different muscle group as compared to the other experiments.

Although a comparison of Lehman's curve with Kolarec's curve, which is plotted using the same time period, would appear to suggest a work decrement all along the scale, the data do not support such a hypothesis inasmuch as Kolarec's workers were slower than Lehman's even during the first minute's work at the lowest weight, suggesting that this difference can be attributed to the difference in the basic abilities of the two working groups used.

The theoretical amounts of work that would be performed, if the heavier weights did not slow down the workers, can be shown by a 45° line passing through the intercept of any of the experimental curves on the Y axis (one-pound ordinate). The difference between the intersection of this line with any ordinate erected on an

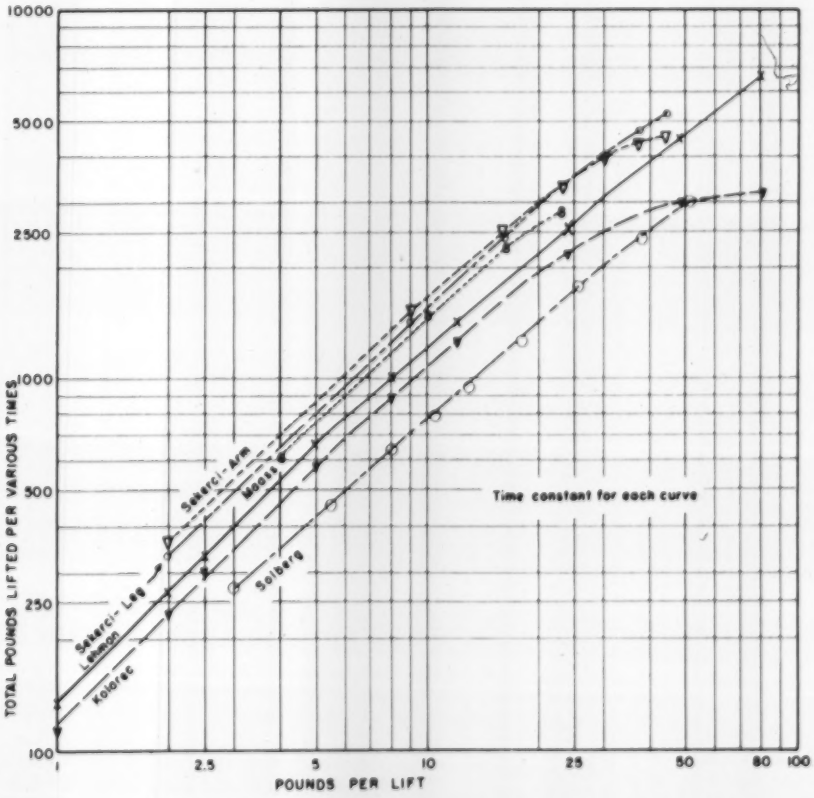

Fig. 2. Plot of Total Weight Lifted Against Weight Per Lift (Log Log Grid)

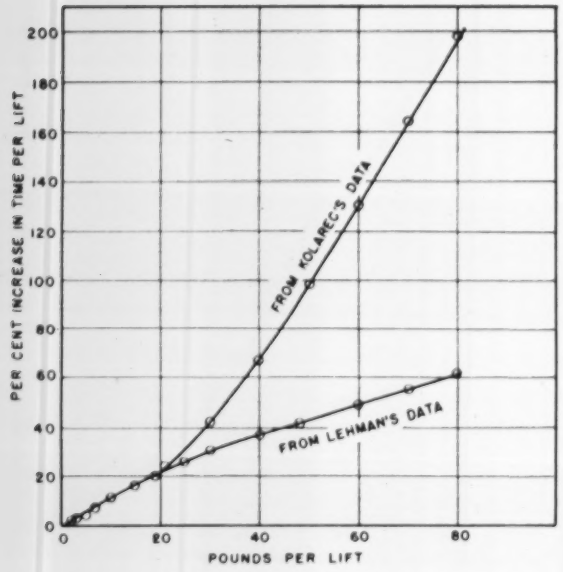

FIG. 3 Percent Additional Time as a Function of Pounds Per Lift (Lehman and Kolaree).

abscissa value and the intersection of the same ordinate with an experimental curve would be the work lost, at that weight lift, as indicated by the particular experiment, from the theoretical work capacity (based on a maintenance of the same pace as with the 1 pound lift). In all cases this is obviously a function of the weight lifted. Trend lines were fitted to Lehman's and Kolaree's data after changing Lehman's scale so as to cause it to coincide with Kolaree's curve (taking these two as the most realistically representative of all the data). These last two experiments certainly were closest to actual work conditions and workers.

Conclusions

$\Delta T = \phi W^{z} \frac{Tl}{Tc}$ for a given muscle group

When:

ΔT is the work decrement, expressed as additional time per lift.

W is the weight per lift.

Tc is the time per cycle including rest and work.

Tl is the time of the cycle during which the worker is performing a lift or exerting force or making movements with load-connected-tension.

$\sum \frac{Tl}{Tc} W^{z} = KW^{z}$ for all muscle groups and all conditions of $\frac{Tl}{Tc}$ for the range of 1 to 19 pounds, hence,

$\Delta T = \phi K W^{z}$

The last Equation can be extended to all muscle groups involved in the different experiments if a flat correction for the difference between Sekerci's "arm" and "leg" curves is extracted separately.

Recommendations

To put the data obtainable into usable form, Lehman's curve was superimposed on Kolaree's and a 45° line passed through the combined intersection on the Y axis at one pound per lift. Using this 45° line, the theoretical, total pounds overcome per unit of time was calculated for each lift, by 1-pound increments. This value was divided by the actual, total weight lifted at each weight per lift (by pounds) using the slopes of both Lehman's and Kolaree's curves, and the excess over 1.00 used as representative of the per cent increase in time due to the weight per lift. The slopes of Lehman's curve yielded the per cent increase in time when the load-connected-work was only 5% of the cycle. The two sets of data were identical up to and including 19 pounds per lift.

Inasmuch as an objective rating applied to a work element converts the time taken to the time that would be taken with the standardized pace (and no difficulty) the time obtained after rating would be similar to the time at one pound (or no load) and expressed on the graph as the 45° line. Hence, the time increment from the 45° line to Lehman's or Kolaree's curve would be the secondary adjustment for weight expressed as a function of the pounds per lift. An assumption was made that the additional increment from 5 per cent of the time to 50 per cent of the time under load was linear, and Table III was computed.

It is to be noted that if a rated element is 50 per cent of the work cycle it will be more than 50 per cent of the working cycle after the adjustment is added to it. At first glance this suggests a second correction. However, the computed adjustments would appear to have been subjected to a maximizing influence in Kolaree's experiment by "pushing" the workers considerably past the comfortable pace. Indeed, despite the use of some very light boxes, they lifted boxes at the rate of 15,710 pounds per hour for each of the three hours of the experiment. This pace, extended through the work day, would be 120,000 pounds per eight hours. In short, although the data were gathered at a constant level of effort, the level was in excess of what is usually expected, and the heavier boxes may have had a maximum effect. Consequently, Table III is suggested as an interim solution[2] for use with objective rating until we learn more about the problem. Table III would be used, in objective rating, as follows:

Let us assume that the task after rating has two elements, (a) .15 min., (b) .10 min.

Element (b) involves motions connected with moving a 47 pound box or giving a 47 pound pull on a lever.

Element (b) is 40% of the rated cycle time, $\frac{.10}{.25}$

[2] It is suggested that one should not attempt to use Table III for a "fatigue allowance table" unless the rater is certain that no attention is given to the effect of weight handled or resistance overcome in the formation of the "normal pace" for comparison. This is not a likely situation with subjective rating.

TABLE III

Per cent Secondary Adjustment as a Function of Per cent of Cycle Time under Load or under Load Connected Work Tension

(Per cent of cycle computed from rated times without adjustments)

Pounds of Force per Lift	Basic Value When Work Under Load is 5 Per Cent or Less of Cycle	Increments To Be Added to Basic Value for Load Connected Work in Per Cent in Excess of 5 Per Cent of Cycle														Maximum Possible Total
		1	2	3	4	5	6	7	8	9	10	20	30	40	45	
1	1															1
2	2															2
3	3															3
4	3															3
5	4															4
6	5															5
7	7															7
8	8															8
9	9															9
10	11	Use basic value for all conditions up to 20 lbs. lift or force per application														11
11	12															12
12	13															13
13	14															14
14	15															15
15	16															16
16	17															17
17	18															18
18	19	When adding up to get value, use nearest whole per cent to total sum														19
19	20															20
20	21	.0	.1	.1	.2	.2	.3	.3	.4	.4	.5	1	1.3	1.7	2	23
21	22	.0	.1	.1	.2	.2	.3	.3	.4	.4	.5	1	1.3	1.7	2	24
22	23	.1	.1	.2	.3	.3	.4	.5	.5	.6	.7	1.3	2.0	2.8	3	26
23	24	.1	.2	.3	.4	.4	.5	.6	.7	.8	.9	1.8	2.7	3.6	4	28
24	25	.1	.2	.3	.4	.6	.7	.8	.9	1.0	1.1	2.2	3.3	4.4	5	30
25	26	.1	.3	.4	.5	.7	.8	.9	1.1	1.2	1.3	2.7	4.0	5.3	6	32
26	27	.2	.3	.5	.6	.8	.9	1.1	1.2	1.4	1.6	3.1	4.7	6.2	7	34
27	28	.2	.4	.5	.7	.9	1.1	1.2	1.4	1.6	1.8	3.6	5.3	7.1	8	36
28	29	.2	.4	.6	.8	1.0	1.2	1.4	1.6	1.8	2.0	4.0	6.0	8.0	9	38
29	30	.2	.4	.7	.9	1.1	1.3	1.6	1.8	2.0	2.2	4.4	6.7	8.9	10	40
30	31	.2	.5	.7	1.0	1.2	1.5	1.7	2.0	2.2	2.4	4.9	7.3	9.7	11	42
31	31	.3	.6	.9	1.2	1.5	1.9	2.2	2.5	2.7	3.1	6.2	9.3	12.4	14	45
32	32	.3	.7	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.2	6.7	10.0	13.3	15	47
33	33	.4	.7	1.1	1.4	1.8	2.1	2.5	2.8	3.2	3.6	7.1	10.6	14.2	16	49
34	34	.4	.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	8.0	12.0	16.0	18	52
35	34	.4	.9	1.3	1.8	2.2	2.7	3.1	3.6	4.0	4.4	8.9	13.3	17.8	20	54
36	35	.5	1.0	1.5	2.0	2.4	2.9	3.4	3.9	4.4	4.9	9.7	14.7	20.6	22	57
37	36	.5	1.1	1.6	2.1	2.7	3.2	3.7	4.3	4.8	5.3	10.7	16.0	21.4	24	60
38	36	.6	1.2	1.7	2.3	2.9	3.5	4.0	4.6	5.2	5.8	11.6	17.3	23.1	26	62
39	37	.6	1.2	1.9	2.5	3.1	3.7	4.4	5.0	5.6	6.2	12.4	18.7	24.9	28	65
40	37	.7	1.4	2.1	2.8	3.4	4.1	4.8	5.5	6.2	6.9	13.8	20.7	27.6	31	68
41	38	.7	1.5	2.2	2.9	3.7	4.4	5.1	5.9	6.6	7.3	14.7	22.0	29.3	33	71
42	38	.8	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.0	16.0	24.0	32.0	36	74
43	39	.8	1.7	2.5	3.4	4.2	5.1	5.9	6.8	7.6	8.4	16.9	25.3	33.8	38	77
44	40	.9	1.8	2.7	3.6	4.4	5.3	6.2	7.1	8.0	8.9	17.8	26.6	35.6	40	80
45	40	1.0	1.9	2.9	3.8	4.8	5.7	6.7	7.6	8.6	9.6	19.1	28.7	38.2	43	83
46	41	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	20.0	30.0	40.0	45	86
47	42	1.0	2.1	3.1	4.2	5.2	6.3	7.3	8.4	9.4	10.5	20.9	31.3	41.8	47	89
48	42	1.1	2.2	3.3	4.4	5.6	6.7	7.8	8.9	10.0	11.1	22.2	33.3	44.4	50	92
49	43	1.2	2.3	3.5	4.6	5.8	6.9	8.1	9.2	10.4	11.6	23.1	34.7	46.2	52	95
50	43	1.2	2.4	3.7	4.9	6.1	7.3	8.6	9.8	11.0	12.2	24.4	36.7	48.9	55	98
51	44	1.3	2.5	3.8	5.1	6.3	7.6	8.9	10.1	11.4	12.7	25.4	38.0	50.7	57	101
52	44	1.3	2.7	4.0	5.3	6.7	8.0	9.3	10.7	12.0	13.3	26.7	40.0	53.3	60	104
53	45	1.4	2.8	4.1	5.5	6.9	8.3	9.6	11.0	12.4	13.8	27.6	41.3	55.1	62	107
54	46	1.4	2.8	4.3	5.7	7.1	8.5	10.0	11.4	12.8	14.2	28.4	42.6	56.9	64	110
55	46	1.5	3.0	4.5	6.0	7.4	8.9	10.4	11.9	13.4	14.9	29.8	44.6	59.5	67	113
56	47	1.6	3.1	4.7	6.2	7.8	9.3	10.9	12.4	14.0	15.6	31.3	46.6	62.2	70	117
57	47	1.6	3.2	4.9	6.5	8.1	9.7	11.4	13.0	14.6	16.2	32.4	48.6	64.9	73	120
58	48	1.7	3.4	5.1	6.8	8.4	10.1	11.8	13.5	15.2	16.9	33.8	50.7	67.6	76	124
59	48	1.8	3.5	5.3	7.0	8.8	10.5	12.3	14.1	15.8	17.6	35.1	52.7	70.2	79	127
60	49	1.8	3.6	5.4	7.2	9.0	10.8	12.6	14.4	16.2	18.0	36.0	54.0	72.0	81	130

TABLE III—*Continued*

Pounds or Force * per Lift	Basic Value When Work Under Load is 5 Per Cent or Less of Cycle	Increments To Be Added to Basic Value for Load Connected Work in Per Cent in Excess of 5 Per Cent of Cycle														Maximum Possible Total
		1	2	3	4	5	6	7	8	9	10	20	30	40	48	
61	50	1.9	3.7	5.6	7.5	9.3	11.2	13.1	14.9	16.8	18.7	37.4	57.0	74.7	84	134
62	50	1.9	3.9	5.8	7.7	9.7	11.6	13.5	15.5	17.4	19.3	38.7	58.0	77.3	87	137
63	51	2.0	4.0	5.9	7.9	9.9	11.9	13.8	15.8	17.8	19.8	39.6	59.4	79.1	89	140
64	51	2.1	4.1	6.2	8.3	10.3	12.4	14.5	16.5	18.6	20.6	41.3	62.0	82.7	93	144
65	52	2.1	4.2	6.3	8.4	10.6	12.7	14.8	16.9	19.0	21.1	42.2	63.3	84.5	95	147
66	53	2.2	4.3	6.5	8.6	10.8	12.9	15.1	17.3	19.4	21.6	43.1	64.6	86.2	97	150
67	53	2.2	4.5	6.7	9.0	11.2	13.5	15.7	17.9	20.2	22.4	44.8	67.3	89.8	101	154
68	54	2.3	4.6	6.9	9.2	11.4	13.7	16.0	18.3	20.6	22.9	45.7	68.6	91.6	103	157
69	54	2.4	4.7	7.1	9.4	11.8	14.1	16.5	18.8	21.2	23.6	47.1	70.6	94.2	106	160
70	55	2.4	4.8	7.3	9.7	12.1	14.5	17.0	19.4	21.8	24.2	48.4	72.6	96.9	109	164
71	56	2.5	4.9	7.4	9.9	12.3	14.8	17.3	19.7	22.2	24.6	49.3	74.0	98.7	111	167
72	56	2.5	5.1	7.6	10.1	12.7	15.2	17.7	20.3	22.8	25.3	50.6	76.0	101.3	114	170
73	57	2.6	5.2	7.8	10.4	13.0	15.6	18.2	20.8	23.4	26.0	52.0	78.0	104.0	117	174
74	58	2.6	5.3	7.9	10.6	13.2	15.9	18.5	21.2	23.8	26.4	52.8	79.3	105.8	119	177
75	58	2.7	5.4	8.1	10.8	13.6	16.3	19.0	21.7	24.4	27.1	54.2	81.3	108.4	122	180
76	59	2.8	5.6	8.3	11.1	13.9	16.7	19.4	22.2	25.0	27.8	55.5	83.3	111.1	125	184
77	59	2.9	5.7	8.6	11.5	14.3	17.2	20.1	22.9	25.8	28.7	57.3	86.0	114.7	129	188
78	60	2.9	5.8	8.7	11.6	14.5	17.5	20.4	23.3	26.2	29.1	58.2	87.3	116.5	131	191
79	61	3.0	6.0	8.9	11.9	14.9	17.9	20.8	23.8	26.8	29.8	59.5	89.3	119.1	134	195
80	61	3.0	6.1	9.1	12.2	15.2	18.3	21.3	24.4	27.4	30.4	60.8	91.3	121.8	137	198

For 47 pounds, Table III gives a basic value of 42% and an additional increment of 36.5 per cent or, in round figures, 37% for the 35 per cent of the cycle more than the minimum 5 per cent of the cycle affected by the weight. (Note that the values given for each weight permit the rapid calculation of the increment for any per cent of cycle under load (or with load-connected-motions) from 5 per cent of the cycle (the minimum value), to a maximum value at 50 per cent of the cycle.)

Consequently, the secondary adjustment for weight for element (b) is 42 + 37 or 79 per cent. This would be used together with the other applicable adjustments to complete the objective rating and adjustment procedure.

The table may be used for leg lifts by using only the basic 5 per cent of cycle value and the 10 per cent adjustment (8) for "leg lift".

It is further suggested that if these computations create a total lift in excess of 120,000 pounds per eight hours, that a "dummy" delay element be added to bring the work load down to this figure.

Also, it is suggested that *carrying an object axially loaded on the body* (or held against the body) be treated as a "leg lift" rather than as an "arm" or "arm and trunk lift". A quick inspection of the muscles involved will indicate the reason for this suggestion.

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By Gerald Nadler

Professor and Head, Department of Industrial Engineering, Washington University

Many of us have watched AIIE grow, and have been astounded by its amazing record. Chapters are being added at a phenomenal rate, and membership continues to grow with equal strides.

The gathering of Industrial Engineers into one group is significant. When we joined, we had a common purpose, and if anything, this purpose has been solidified and enlarged. Because the growth has been so great, it is important to stop a moment and look back as well as forward. It is important to evaluate our profession of Industrial Engineering, to evaluate AIIE, and to evaluate ourselves for the purpose of assessing our continued growth as a profession, group, and individuals.

Our Profession

Industrial Engineering has several definitions provided by various people, but the recent definition of our profession provided by the AIIE is probably the best available. "Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of men, materials, and equipment. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems."

A corollary consideration of Industrial Engineering is to assess the need for such activity. It is one thing to define an area, and another to establish its need. Certainly, the reason Industrial Engineering has developed in the past 60 to 80 years is that engineers had to start looking at the complexity of the whole situation rather than the individual case. In general, the engineer had always been required to deal with the design or improvement of a specific, rather small, situation. It was the design of a piece of equipment, or of an electrical process, or a bridge across a specific river. In almost all these illustrations, the situation was relatively limited, both in terms of its complexity and the items with which the engineer must deal, and in relation to the fact they dealt with material factors, not human factors.

The growth of the complex industrial organization required the approach which dealt with a design of the system involving material *and* human factors. Because this is a specific engineering concept, which deals with putting together various engineering designs of individual components, the growth of Industrial Engineering became a necessity.

The importance of our field has been demonstrated many times. Designing these systems has been interesting and profitable. Each of us has had opportunities to apply Industrial Engineering to several areas which indicate the importance of our design work on complex systems. It is worthwhile, however, to mention several areas to illustrate further the wide application of Industrial Engineering.

What Has Industrial Engineering Done?

The usual applications of industrial engineering in the areas of quality control, production planning, production control, motion and time study, plant layout and materials handling, tool engineering, wage incentives, and so forth are familiar to many. However, years have seen new areas of application. For example, one company in St. Louis now requires an Industrial Engineering staff member to be part of all discussions concerning designs of new products. Another large company in St. Louis stipulates that no building or plans for building should be approved until the Industrial Engineering Department has approved the designs. In effect, this means that the structure itself is built around the process to be performed, rather than the usual reverse situation.

At the present time hospitals are an important new area for applying Industrial Engineering. There is a medium-sized hospital in St. Louis where Industrial Engineering techniques and practices are being applied for developing the staffing patterns for nursing personnel. This is a true engineering function, requiring imagination and good application of principles to arrive at the solutions. Universities represent ripe areas for the application of Industrial Engineering. The department of Industrial Engineering at Washington University has worked on a complete registration procedure study. The business office of any University is an area which has been sacrosanct for many years, yet needs Industrial Engineering more than many other activities.

Governmental agencies have started to realize the

* Based on talks presented to the Mississippi Valley Chapter AIIE, May 1955, and Wichita Chapter AIIE, May 1956.

benefits of Industrial Engineering. The post office in the past several years has established an Industrial Engineering Department which promises to provide great savings. In addition the ordnance corps of the Army has established a training program in Industrial Engineering topics for its large staff. Insurance companies and their tremendously numerous and complex office procedures, are using Industrial Engineering talents to design their systems and flow.

All in all, what Industrial Engineering does has indicated both the requirements and need for such activity.

One important concept concerns the approach to people in conjunction with technical engineering. This truly differentiates the Industrial Engineering from the other branches. It is important never to forget the human being and his place in the system. This even applies when the human being will not be needed in the system, and the Industrial Engineer has to solve the problems thus posed.

The definition of Industrial Engineering offers another reason for the growth of Industrial Engineering. Engineering might be defined as the art of controlling the forces and materials of nature, and organizing and directing men, for the benefit of the human race. The branches of civil, mechanical, electrical, and chemical engineering provided for the first part of the definition, but the second part was not taken care of. The new branch of Industrial Engineering was needed.

We Know We Need Industrial Engineering, Now What?

It is my belief that Industrial Engineering has reached a point where we no longer have to spend most of our energy on establishing the need and desirability of Industrial Engineering. This does not mean there isn't much to be done. But, in many ways, the remaining "selling" is a mopping-up operation, rather than the main battle. The Industrial Engineer has been almost completely accepted into all of our large organizations and universities. We must face the next task at hand.

Establishing the professional nature of our field is the next step in our growth. We feel professional recognition is past due, because of the good procedures and techniques we use. Industrial Engineering on its own deserves professional recognition, without the necessity for "fighting" for this recognition. The reason for planning the next stage of our growth is that it will help achieve this recognition years before it might accrue as a natural development. This is similar to what every other branch of engineering did in its infancy.

There have been many definitions of what constitutes professional recognition. Perhaps it is not as important to define professional recognition as it is to establish how it was achieved by other groups. However, it is apparent that professional recognition involves a fundamental understanding of the technical information used by the field, the service it gives to those who use the service, its recognition of the social obligations, and the recognition by the social world of the professional nature of the area.

The development of the other branches of engineering help show us what it took to achieve professional recognition. Simplifying the process as much as possible, we find there are three essential steps.

Steps in Growth of a Profession

1. *There was a need.* A job had to be done. The bridge had to be built. The lathe had to be designed. An electric motor had to be constructed. A cracking tower had to be put into operation. And, of course, a system had to be designed to incorporate several pieces of equipment into an integrated whole.

When each problem first arose, there was no engineer to solve it. There were no people with degrees to help take care of the situation. The problems had to be solved by using logic and empirical procedures. In this sense, the people who solved the problems were the pioneers of the time. They helped to establish the footing on which the engineering profession grew. And it is important to notice these pioneers were necessary. In no other way could the profession of any engineering branch get started.

2. *Facts became established.* The man who solved one of the above problems gained a certain amount of experience. He applied this experience to a somewhat similar problem again. He learned something new. After a while, certain facts became relatively well known. These facts became the first foundations of the field.

As some of the problems, that had to be solved in the early days of any branch of engineering, became more complicated, then some of the research areas began to develop. In this phase, some of the experience, when combined with the research of the academician, provided a more concrete foundation for the field. As must be recognized, this step provided ever increasing numbers of facts and figures about the problems of the area. In many cases, the facts became either so numerous that it was difficult to know what all of them meant, or some of the facts became contradictory and chaos appeared a likely result in the field.

3. *Facts become unified into basic and simple theories.* One of the seeming paradoxes of any field is the fact that when numerous facts are established, it is frequently possible to develop a simple theory to combine much of the known information. In many cases, the myriad facts seem so complex that a simple theory appears out of the question. However, simple theories are developed from complex facts.

In situations like this college degrees start to become essential for personnel in the field. Additional training is needed to not only solve present day problems, but to plan for the solution of tomorrow's problems. Although simple theories are evolved, this does not mean there is a slow down in the process of learning still more through experience and research. Additional facts are obtained and they seem to be complex. Simple theories are evolved from

these complexities. Thus, professional status is achieved. And research and experience continue to develop further theories and concepts.

Where is Industrial Engineering?

To me it appears that Industrial Engineering is now located somewhere between steps two and three. Certainly, we have plenty of facts. Now we are in the process of trying to put these facts into some overall theories. At the present time, only tentative *real* theories have been developed. But the air is full of this important work. And although this means we may not be exactly "right" for complete recognition, we are close to this status.

One problem of recognition, in the professional sense, is the necessity for establishing one group to help formulate and communicate the concepts and theories being developed. In the days of the pioneers of any field, it was ridiculous to try to get the practitioners of the day together in one group because each felt quite secure in his own experience and abilities in solving the problems. But as a field progresses through steps two and three of its growth, it becomes more essential for those practicing in the field to get together to exchange information, and to aid in the establishment of these theories and concepts so essential to professional growth. Therefore, one objective of any professional group would be to provide the meeting place or forum for establishing the basic and simple theories. As can be recognized, the AIIE fulfills this need.

There were other attempts at unification in Industrial Engineering. Certainly the Taylor Society, the Society for Industrial Engineers, and even the Society for Advancement of Management, attempted to be the unifying force for industrial engineering. It seems to me these groups failed because we had not progressed beyond step one. Each man's experience varied, and he could not quite see why his experience should not be provided first-place in any concept formulation; therefore, the downfall of the proposed purpose of the organizations. These organizations did provide many opportunities for discussions among these pioneers, but they did not have sufficient facts, through experience and research, on which to base their unifying principles. Now, though, it is becoming more apparent that there are some cohesive concepts, and that the AIIE is a catalyst in providing the formulation of these concepts. Now let us discuss the AIIE and assess its value in this growth of professional recognition.

AIIE and Professional Recognition

In addition to the role of trying to develop the form wherein unifying concepts and theories are developed, the AIIE also is the prime mover in establishing professional recognition among groups other than Industrial Engineers. Without question, this is one of the most important activities of any group such as AIIE, and our organization has had remarkable success in this line.

Other engineering branches have started to recognize Industrial Engineering through the efforts of the AIIE. They present our present technical developments to others, and establish relationships which are worthwhile. For example, it is now becoming desirable to point out the relationship of Industrial Engineering to architecture. The design of buildings, plants and warehouses is becoming an important segment of our work, and this joint relationship must be done.

The AIIE presents a united front for Industrial Engineering on the Engineers Joint Council (EJC), being an associate member of this group. In addition the AIIE now specifies members of inspection teams for ECPD, (Engineers Council for Professional Development) when these teams visit the Universities for accreditation purposes. Our professional recognition among other societies has been notably increased.

And, of course, the AIIE provides the means for getting recognition of Industrial Engineers in the community. A chapter located in a metropolitan area can do much to develop professional recognition for Industrial Engineers. But this chapter would not be nearly as effective if it were just a local chapter, rather than one associated with a National organization. The strength of unified chapters is overwhelming.

There are other areas in which AIIE is an important factor. The problems of our professional recognition are also the problems of professional recognition for the whole field of engineering. Each of us has heard of many types of engineers; at least, the word "engineer" was used, for example, the brake engineer, the train engineer, the hoisting engineer, etc. These are not true engineering fields, nor should the term engineering be used to designate these kinds of activity. AIIE must help establish unifying concepts for all engineering as well as for Industrial Engineering alone; this is important for our professional development. The establishment of unifying concepts for all engineering fields is part of step three mentioned above, since all engineering is going through the same professional development process.

Professional Development Implies Continued Growth

Getting professional stature does not in any way reduce the need for continued work in developing new concepts and applications. As a matter of fact, it increases the need. There are many areas that will need much Industrial Engineering work in the coming years.

Automation is a big factor in our future. The handling concepts implied in automation are well within the Industrial Engineering realm. The design of parts and products, layout, work assignments, schedules, manufacturing sequence, etc., are problems in automation. These problems will require more Industrial Engineers. These are in addition to the problem of obtaining greater utilization of technical man power.

One of the choice problems in the future will be how to increase the productivity of an automated plant. Many people assume that an automatic factory has achieved

optimum in production. This is sheer nonsense. There are several ways to develop still greater productivity in an automated plant, better utilization of the present equipment and handling devices, better processes and physical equipment, better utilization of man power and many more. Finding these answers is within the realm of Industrial Engineering. Part of the productivity development of our country will depend on future Industrial Engineering activities.

There are still many other work activities where it will be extremely difficult to effect automation. Hospitals offer an illustration of where much non-repetitive work is being performed. Industrial Engineering will have to find ways of utilizing the skilled man power in such situations with more and newer techniques.

The horizon is even broader. Mathematical programming will play an important role in coming years. Electronics for controls and research are growing in importance. Computers and Industrial Engineering will become even more interrelated. Bio-mechanics will shape many Industrial Engineering applications. Even work measurement will have to find methods for measuring how much work can be assigned to an individual in an automated plant. This will be even more important than present-day work measurement. Each person will represent a huge investment, thereby requiring that the work load assignment be made more accurately.

All engineers are becoming more conscious of the human problem. This is an important development. This awareness takes several forms, one of which is the recognition that people must participate in activities which change their work. The automatic factory represents social and community peoblems which have to be solved, not only by politicians but by the engineers who helped develop this concept. Additional leisure time for workers will require additional non-working facilities. The Industrial Engineers will be required to apply techniques to achieve greater utilization of such facilities.

An increasing fund of knowledge provides the basis for making Industrial Engineering even more cohesive. In effect, professional growth continues. But an amazing point here concerns the fact that this growth can not be expected unless the individual Industrial Engineer contributes. In other words, professional recognition cannot in any way depend upon an intangible grouping. It must depend upon the individuals.

You and Professional Recognition

To depend on an organization to push yourself and your professional development is the worst type of thinking. The whole purpose of the Industrial Engineering field is to provide answers to problems on the operating scene. These answers can be developed better if there is a large fund of information and concepts on which the individual Industrial Engineer can draw. Answers will come easier when others recognize that Industrial Engineering does have a professional background and a wealth of information on which to draw. This means the individual on the "firing line" is the person who can decidely effect the growth of the profession and the recognition of the profession in the eyes of others. Each individual must promote, not only recognition, but the development of the field in new and broader areas. Developing new principles and applications is one of the most important objectives of Industrial Engineering.

The second function of the individual Industrial Engineer is to work within the group that has been established in the profession. In such a group, the individual has an opportunity to discuss his problems with other people with similar situations on the same local scene. By exchanging information with others, new concepts and a more useful knowledge bank can be established. The personal contacts are essential to the professional development of the Industrial Engineer. Solving current operating problems leads to the development of the theories and concepts which are needed in future work.

A well-informed individual Industrial Engineer operating at his daily problems presents the best hope for the future professional development of Industrial Engineering. But the individual cannot operate successfully unless he has a group in which to disseminate and receive information. This makes the local chapter of AIIE by far the most important unit in the whole profession. For it is here that the ideas of the various members can be exchanged to develop the needed concepts and theories for the field.

With strong local chapters, there can be no question that the American Institute of Industrial Engineers can develop necessary concepts which are needed for the field, as well as presenting a united professional face to the outside world. Only the growth of the field itself can spur the professional recognition which we seek.

It appears, without question, that the future for Industrial Engineering is bright, even beyond the imagination of the most optimistic in our group. Growth of the professional field spurs professional recognition. And professional recognition, through the American Institute of Industrial Engineers, spurs the growth of the professional field itself through the individual. If we grow, our profession grows. If our profession grows, we grow. These are inseparable, and both must help the other.

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Differential Profit Control—A Modernization of the Break-Even Analysis

By Dr. Raymond Villers

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Rarely, if ever, does the industrial engineer have the choice between big profit and big loss. As a rule, his task consists in making a decision involving a choice between a reasonably good solution and a probably better one. To do so, the Industrial Engineer wants a clear picture of the situation and also, if at all possible, a quantitative measurement of the factors involved and of their inter-relationships.

The traditional equation of accounting:

$$\text{Profit} = \text{Sales} - \text{Cost}$$

does provide a very useful framework of reference, but to a certain extent it is a misleading over-simplification. Profit cannot, as a rule, be increased by merely increasing sales, on the one hand, and or decreasing cost, on the other hand.

The method of differential profit control is an attempt to provide the necessary tool to analyze a whole situation through the use of a mathematical model which truly reflects the complexity of the problems of profit control. This article will present this method and show through examples how the industrial engineer can use it and benefit from it.[1]

Whether an industrial engineer specializes in work measurement, or in methods and processes, or in plant lay-out, or in any other specific aspect of the complex world of industrial management, whether or not he has also been active in the field that some people continue to call "Operations Research" while some others—including the writer prefer to call it "A continuation of the best in Industrial Engineering",[2] in any case, there is one fundamental problem that he must face, day-in, day-out. It is the problem of profit optimization.

This problem can be best understood by fully realizing that the fundamental characteristic of the modern industrial enterprise is that of being closely integrated. There is hardly any single element of the organization that exists on its own. Everything has to be considered as part of a whole, as supporting some activities and as being supported by other activities.

The more efficient the organization is, the closer this integration becomes, resulting in a complex structure of inter-relationships.

Translated in terms of dollars and cents, this means that profit is *not* the mere difference between two independent variables, sales on the one hand and expenses on the other hand. Instead, profit is the result of a series of relationships.

The relationships involved can be classified in three main groups:

First: The cost to sales relationship, which is characterized by the fact that some costs vary directly with sales, such as the cost of materials, for instance, while others are totally unrelated to sales, such as the real estate taxes involving the plant itself, and others vary with sales but not directly, such as the supervisory expense, for instance.

Second: The cost to cost relationship, illustrated by the fact that, for instance, new and more efficient equipment increases the depreciation cost but reduces the labor cost.

Third: The sales to sales relationship, which involves pricing policies and marketing considerations. The sales of some products conflict with the sales of other products, while some sales, on the contrary, may stimulate the sales of another line of products. Some products are the origin of more extensive and more rigid overhead than others. For this reason, and also because pricing policies are related to competition and cannot be rigidly connected with the cost of production, some items are much more profitable than others. Ultimately profit will largely depend upon the sales mixture as well as upon the total volume of sales.

Differential Profit Control

The mathematical model used in the method of differential profit control reflects these three fundamental relationships. It is a further development of the break-even chart originally developed by Walter Rautenstrauch.

[1] This method was originally presented by the writer at the Seventh National Convention of the AIIE in 1956. For more details on the whole concept of break-even analysis, see Rautenstrauch and Villers, *The Economics of Industrial Management* (Revised edition, Funk and Wagnalls, 1957).

[2] See George P. Champion's "A Continuation of the Best in Industrial Engineering", in *The Journal of Industrial Engineering*, July-August, 1956.

An example will illustrate: Let us say that for the year 1956 the profit and loss statement of the ABC Co. shows the following results (in $ millions)

Total sales		$15.0 M.
Cost of goods sold	$10.0	
Selling expense	2.0	
Administrative expense	1.5	
Total Expenses		13.5
Net profit before taxes		$1.5

and that the analysis of cost provides the following figures:

Labor	$3.0 M.
Material	5.0
Other variable costs	2.0
Total variable	$10.0
Total constant	3.5
Total cost	$13.5

Figure 1 shows the break-even chart obtained in plotting sales in abscissa and cost in ordinate, using the same scale.

The trend expense to sales is defined by the equation:

$$y = a + bx$$

where

y = total expense
x = total sales
a = constant expense
$b = \frac{v}{s}$ = ratio variable expense to sales

In this case, $y = 3.5 + .66x$

This equation is valid only within a certain range of variation of the volume of production and only as long as the conditions of operation remain unchanged.

If the sales of the ABC Co. should increase or decrease, the variable expense v is still defined by the equation:

$$v = bx = .66x$$

but certain elements of constant expense, the supervisory expense and office salaries, for instance, and a few others,

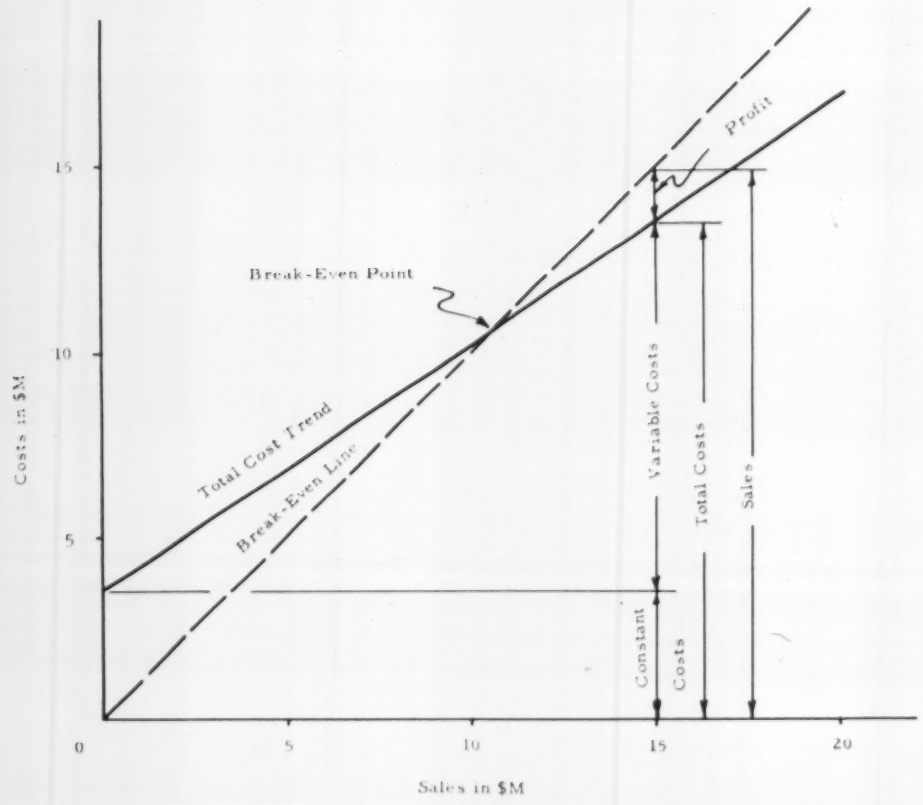

Fig. 1 The ABC Company—Break Even Chart

would have to be increased or decreased. So the constant factor would no longer be

$$a = 3.5$$

If, in addition, some progresses were made in methods and processes which increase labor efficiency, then the slope of the trend decreases:

$$c \text{ is not } .66x \text{ any more}$$

If there should be a change in the sales mixture, the slope of the trend is further modified.

Do these considerations affect the usefulness of the break-even chart? Certainly not, as well proved by its increasing adoption by industry.[3] Its usefulness results essentially from two characteristics:

1. The chart provides a linear equation which defines the cost to sales relationship within a certain range of variation of the volume of production and which remains valid as long as the conditions of operations remain unchanged.
2. When this range of variation of the volume of production is exceeded and or when the conditions of operation change, the chart provides the basis from which the impact of a change can be measured.

It is now proposed to take full advantage of these two characteristics by combining them into one single mathematical model which will provide both the linear equation that defines the cost to sales relationship and the structure within which computations can be made in a comparatively simple manner to measure the impact of a change. This mathematical model is the equation:

$$y = (a + \Delta a) + (b + \Delta b)x$$

where

y = total cost
x = sales
a = constant cost at the time T_0 of the original analysis
b = ratio of variable cost to sales at time T_0
Δa = difference due to a change in constant cost since the time T_0
Δb = difference due to a change in the ratio of variable cost to sales since the time T_0

In the case of the ABC Co., the equation

$$y = 3.5 + .66x$$

thus becomes

$$y = (3.5 + \Delta a) + (.66 + \Delta b)x$$

To compute a and b in a careful manner, admittedly takes time and effort.[4] It is worthwhile doing it from time to time, but it cannot be repeated too often. The essential purpose of the method of differential profit control is to avoid the repetition of such a computation at too frequent intervals.

In the case of the ABC Co., we have

$$a = 3.5 \text{ and } b = \frac{v}{x} = .66$$

as of Jan. 1, 1957.

Let us ask ourselves this question: How can these factors change?

The answer is:

The constant expense of $3,500,000 cannot change without a managerial decision authorizing the change.

The variable expenses do change, more or less, automatically as sales vary, but the ratio $b = \frac{v}{x} = .66$ cannot change substantially unless either one of two happenings occur: either a managerial decision changes the conditions of operations (wage rates, purchase price of new materials, etc.) or the sales mixtures changes.[5]

On the basis of these remarks, it can be said that any modification in the constant expense $a = \$3.5$ millions, or in the ratio of variable expense to sales, $b = .66$ can be automatically detected and subsequently evaluated by merely establishing a routine procedure providing for the recording and then the computation of the impact of:

Any managerial decision involving the conditions of operations and causing a change in the constant expense, $a = 3.5$, or in the ratio of variable expense to sales, sales $b = .66$

Any change in the sales mixture, also causing a change in the ratio $b = .66$

The impact of such changes will be computed as Δa and Δb in the following manner:

$$\Delta a = \sum_{i=1}^{n_0} \Delta a_i + \sum_{i=n_{0+1}}^{n_1} a_i$$

where $\Delta a_1, \Delta a_2, \cdots, \Delta a_{n_0}$ are the differences due to a change in the value of the original elements of constant costs $(a_1, a_2, \cdots, a_{n_0})$,

where $a_{n_{0+1}}, a_{n_{0+2}} \cdots, a_{n_1}$ are additional elements of constant costs that have appeared after the time of the original recording,

and

$$\Delta b = \frac{\sum_{i=1}^{n_0} \Delta v_i + \sum_{i=n_{0+1}}^{n_1} v_i}{x_1} + \Delta b_m$$

[3] The attention given to the break even chart and to its complement, the sales mixture chart, is illustrated by the fact that both have been extensively discussed in recent years in magazines and publications known to be read by industrial executives. See, for instance: *Dun's Review and Modern Industry* (Nov. 1955); A. M. A. *Manufacturing Series* No. 207 (Jan. 1953); *Business Week* (July 1950); *Fortune* (Feb. 1949); *Modern Industry* (Dec. 1948); *New York Times* (Oct. 3, 1948).

[4] For the detailed study of a suggested procedure, see: R. Villers, *The Dynamics of Industrial Management* (Funk and Wagnalls) p. 332 ff.

[5] These remarks do not apply to the job shop. In the case of the job shop, the "learning curve" among other factors exercises a primary influence and thus provides a condition where Δb may have another origin than the ones mentioned above.

where $\Delta v_1, \Delta v_2 \cdots, \Delta v_{v0}$ are the differences due to a change in variable costs, which are related to a change in the structure of the original elements of variable costs $(v_1, v_2 \cdots, v_{v0})$,

where $V_{v0+1}, V_{v0+2} \cdots, V_{v1}$ are new elements of variable costs that have been introduced,

where x_1 is the sales volume corresponding to the variable costs taken into account (adjustments in the computation will be necessary if the variable costs taken under consideration are not all related to the same sales volume x_1),

where Δb_m is the difference due to a change in the sales mixture.

Application - The Case of the ABC Co.

In the case of the ABC Co. the equation of differential profit control:

$$y = (3.5 + \Delta a) + (.66 + \Delta b)x$$

was based upon the conditions of operations existing as of January 1, 1957.

At the end of the first quarter 1957, a break-even analysis is being conducted on the basis of the changes that have occurred and have been duly recorded, as they did occur. This break-even analysis involves the following steps:

Step 1 - Tabulating the changes which affect the constant expense (computed in $ millions on the basis of the annual rate of expense).

1. Because of an increase in production, which has brought production up to $4.8 millions for the first quarter 1957 and is expected to increase further during the year, the supervisory force has been increased:

$$\Delta a_2 = .03 \text{ (in \$ millions)}$$

2. For the same reason, maintenance cost has been increased:

$$\Delta a_6 = .001$$

3. The Board of Directors has increased advertising by:

$$\Delta a_{11} = .05$$

4. Four new items of constant expense have been introduced. One is the rent of a new warehouse:

$$a_{101} = .04$$

The second one is the interest on a long term loan which was required because of lack of working capital to face the increase in production and which amounts to:

$$a_{102} = .06$$

The third one results from the creation of a research department:

$$a_{103} = .05$$

The fourth one results from the introduction of a pension plan for monthly paid employees:

$$a_{104} = .04$$

Step 2 - Computing the differences in the ratio variable expenses to sales (expressed in percent of sales):

1. An incentive plan and some improvement in the methods of work have resulted in an increase of about 10% in labor efficiency. As labor is $\frac{3}{15} = 20\%$ of sales, such an increase in labor efficiency means a reduction of labor cost of about 2% of sales. Thus

$$\Delta b_1 = -\frac{2}{100}$$

2. The increase in production has been made possible by a special sales effort, related to the increase in advertising expense already recorded as Δa_{11}. This effort also included an increase in salesmen commissions and in their traveling expense budget, resulting in

$$\Delta b_{23} = \frac{4}{100}$$

Step 3 - Computing the impact of changes in the sales mixture.

Table A presents the sales mixture analysis of the ABC Co. for the year 1956 and for the first quarter 1957. Fig. 2 is the sales mixture chart reflecting the situation.

All items sold have been grouped according to the direct profit per dollar of sales of each item.[8] At the ABC Co. there are 9 groups. The average direct profit per group

TABLE A

Computation of Δb_m

Group No.	Average Direct Profit (in Percent of Sales Dollar)	Sales (in Percent of Total Sales)		Weighted Average (by Percentage of Direct Profit and Sales)	
		Year 1956	1st Qu. 1957	Year 1956	1st Qu. 1957
(1)	(2)	(3)	(4)	(5)	(6)
1	30	.91	1.22	27.30	36.60
2	35	.76	2.96	25.90	103.60
3	40	12.03	9.78	481.20	391.20
4	45	9.71	26.06	436.95	1171.80
5	50	12.04	8.15	602.00	407.50
6	55	33.05	28.25	1817.75	1553.75
7	60	18.53	11.85	1111.80	711.00
8	65	9.80	9.75	637.00	633.75
9	70	3.19	2.00	223.30	140.00
Total		100.00	100.00	5563.20	5149.20
Average Direct Profit per dollar				55.63	51.49

[8] For an extensive study of direct costing (closely related to the marginal cost theory) and of the sales mixture chart, see Rautenstrauch and Villers, *Budgetary Control*, (Funk and Wagnalls).

varies from 30 cents per dollar of sales for group 1 to 70 cents for group 9. Each of the nine groups includes all items for which the direct profit per dollar of sales is within a range of variation of ±2.5 cents from the average for the group.

The sales per group are shown in column 3 for the whole year 1956 and in column 4 for the first quarter 1957. These sales per group instead of being measured in dollars are measured in percent of the total sales for the period considered. This makes it possible to compare the sales of one period to the sales of any other shorter or longer period.

The total of column 5 provides a weighted average direct profit per dollar of sales for the year 1956 as a whole (55.63 cents per dollar). This compares to the figure of 51.49 cents for the first quarter 1957.

This change is due to the fact that in 1957 the ratio of sales related to the less profitable items was substantially increased (as shown by comparing column 3 to column 4).

The change in average direct profit per dollar of sales shows a decrease in profit:

$$\Delta p = 51.49 - 55.63$$
$$= -4.14$$

This negative change in direct profit per dollar of sales corresponds to an equivalent positive change in the ratio of direct cost per dollar of sales:

$$\Delta b_m = -\Delta p$$

In this case, therefore

$$\Delta b_m = 4.14$$

Step 4 — Incorporating the changes in the equation of differential profit control. In the equation

$$y = (3.5 + \Delta a) + (.66 + \Delta b)x$$

we find:

$$\Delta a = \Delta a_2 + \Delta a_6 + \Delta a_{11} + a_{101} + a_{102} + a_{103} + a_{104}$$
$$= .03 + .001 + .05 + .01 + .06 + .05 + .04$$
$$= .271$$

$$\Delta b = \Delta b_1 + \Delta b_{25} + \Delta b_m$$
$$= -\frac{2}{100} + \frac{4}{100} + \frac{4.14}{100}$$
$$= \frac{6.14}{100}$$

Thus the equation:

$$y = (3.15 + \Delta a) + (.66 + \Delta b)x$$

which represented the situation as of January 1, 1957 becomes as of the end of the first quarter 1957:

$$y = 3.771 + .721x$$

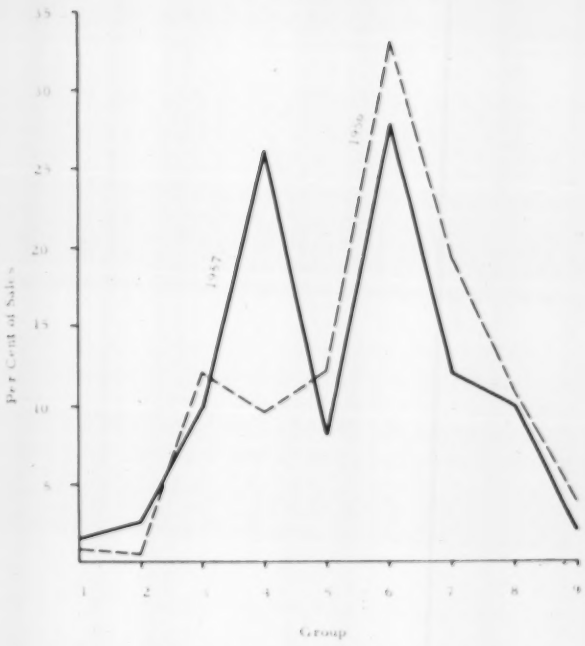

FIG. 2 The ABC Company — Sales Mixture Chart

Possible Use of an Electronic Computer

The above computations are only an illustration of those that have to be performed in actual practice to keep abreast of changes in conditions of operations.

The clerical work involved may eventually be greatly simplified by including the necessary recording and computations in the programming of an electronic computer. In fact, the writer has been advised that the possibility of making the method of differential profit control part of such a programming is currently being studied at the IBM Research Laboratory, Poughkeepsie, N. Y., as part of an extensive research program concerned with Integrated Data Processing problems.

Ultimate Results — Differential Break-Even Chart

From his own point of view, the industrial engineer will find that the method of differential profit control can essentially serve the following purposes:

Determining a reliable standard to which the actual performance can be compared.

Budgeting future expenses in relation to anticipated sales.

Evaluating in quantitative terms the relative worth of alternatives under consideration: choice between purchasing a new equipment or keeping the old one going, choice between new equipment of different prices and different efficiencies, etc.

Finally, it should be noted that the method lends itself to the preparation of what can be called a differential break-even chart. Such a chart is shown in Fig. 3, based upon the case of the ABC Co.

Trend T_1 corresponds to the original equation (as of Jan. 1, 1957):

$$y_0 = 3.5 + .66x$$

Trend T_2 corresponds to the new situation (as of April 1, 1957)

$$y_1 = 3.771 + .721x$$

The use of dotted and plain lines, as shown in Fig. 3, is advisable in such a case because it illustrates the volume at which the change occurs.

By looking at such a single graph instead of going over piles of accounting data, the industrial engineer in charge of studying any situation or any project can see at a glance the impact of actual or proposed changes in the conditions of operations, regardless of the complexity of such changes. Measurements on the graph itself give an immediate answer to such questions as:

1. *What happened to the break-even point?*
   Ans. It was raised from $10.3 M. to $13.5 M.
2. *Are we in a better or in a worse position than before?*
   Ans. The cost to sales relationship was more favorable in 1956 (Trend T_1) than in 1957 (Trend T_2). At the same time however, the new conditions of operations, represented by the trend T_2, have enabled us to increase our sales from $15 M. to an expected volume of $20 M. This increase was made possible by increasing the plant capacity (Δa_2, Δa_6, a_{101}, a_{102}) by increasing the sales effort (Δa_{14}, Δb_{23}) and by accepting to push the sales of the less profitable items (Δb_m). The increase in total sales volume has more than compensated the unfavorable change in the trend of the cost to sales relationship. As a result, the net profit before taxes which was $1.5 M. in 1956 can be expected to be $1.8 M. in 1957. This means an increase of $300,000, in spite of the fact that the trend T_2 is less favorable than T_1.

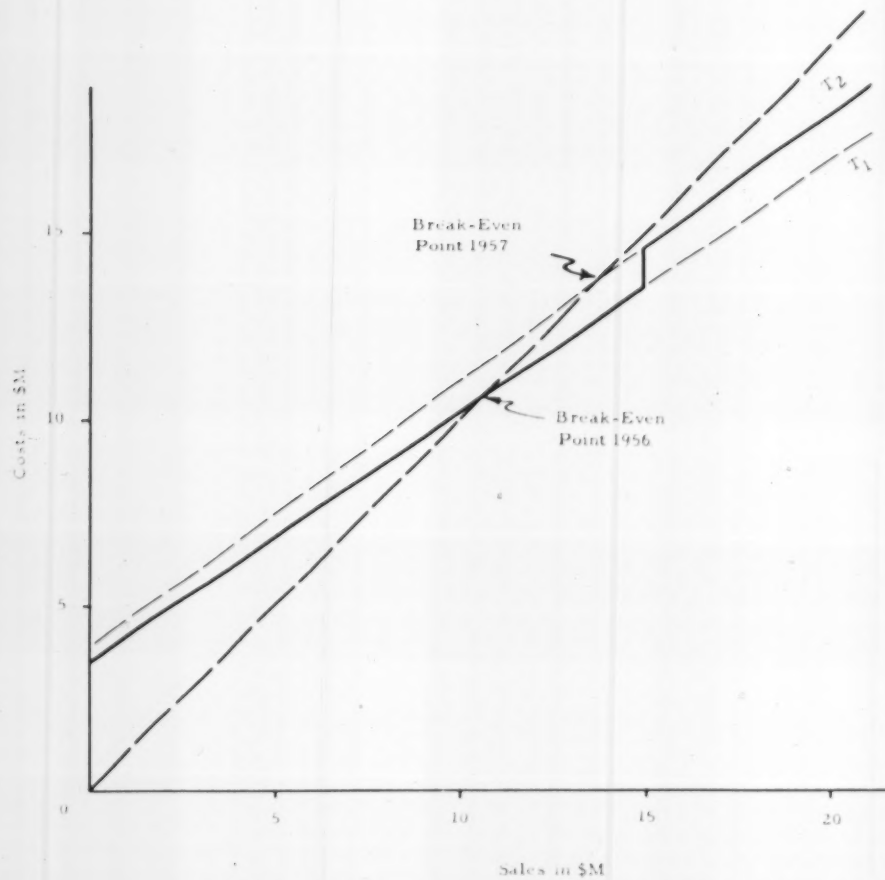

FIG. 3 The ABC Company—Differential Break-Even Chart

The answer to question 2 illustrates the fundamental characteristic of the break-even analysis method which is essentially an attempt to provide a *synthetic* picture of a very complex situation. The accounting figures, on the contrary, can be said to be of an *analytic* character. They provide data related to the sales volume, the various element of costs, the profit per unit, the total net profit, and a multitude of useful details. They do not, however, provide a synthetic picture of the whole situation as the break-even analysis does by combining all factors involved into one single trend which represents the cost to sales relationship under specific conditions of operations, at any given volume of sales.

The impact of any change in the volume of sales can be measured on the break-even chart by plotting sales in abscissa, but such a change does not affect the trend itself unless the conditions of operations are modified, as was the case in the above example where the plant capacity had to be expanded and where the sales effort had to be increased. Fig. 3 shows how, in that case, the trend T_1 (valid up to about $15 M. of sales) had to be changed to enable the company to reach a higher volume of sales. Fig. 3 also shows how the trend T_2 (valid above $15 M. of sales) compares to T_1. The trend T_2 reflects all the changes that have affected the conditions of operation during the period considered including in that case some changes that are not directly related to the increase in production (such as, for instance, the creation of a research department, a_{100}). It also reflects the change in the sales mixture, thus presenting a truly comprehensive picture, in quantitative terms, of the whole situation. This emphasizes the synthetic character of the break-even analysis method.

If further changes related to high policy decisions were to be considered, the trend T_2 would be used as the basis from which to start the computations. The impact of contemplated changes would be determined by evaluating the differences Δa and Δb in the equation:

$$y = (3.771 + \Delta a) + (.721 + \Delta b)x$$

This illustrates the fundamental characteristic of the method of differential profit control which is essentially intended to reduce the work involved in break-even analysis by limiting it, whenever possible, to the computation of differences. The differential break-even chart can be used to show the impact of any change, whether an actual one or one that is under consideration, by merely plotting the trend corresponding to the situation that has been or would be created by the change. The new trend is determined by using either the previous or the present trend as the basis from which to start and evaluate any expected difference.

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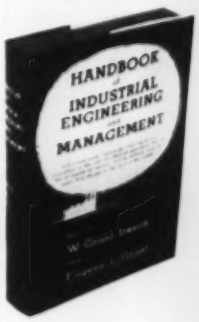

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PRESIDENT'S MESSAGE

OUR FUTURE*

By Gordon B. Carson

President, American Institute of Industrial Engineers, Inc.

I am grateful to all of my AIIE friends for the high honor of being elected your President for 1957 58. The task which we face together should make us all pause a moment, regroup our forces, and prepare to attack our common problems with renewed vigor.

All of the Presidents who have preceded me have made contributions to the growth of AIIE. I am grateful to them for their work in building the foundation upon which we stand.

Organizations, like people, go through infancy with all its childhood squabbles and minor tragedies; and adolescence wherein all problems, large and small, assume equal importance. Some people never escape from adolescence. The period of new bewilderments and many real and imagined frustrations so completely grips them that they deny themselves the silent and competent power of real manhood. So it is with organizations . . . some are filled with adolescent contentions for life.

Fortunately for all of us, men of vision and courage have, in their turn, guided the destiny of our organization, and we have now emerged from our period of adolescence into the full vigor of young manhood. Our task is to use this vigor, as we continue our growth, until we assume our rightful position among other learned societies, and become accepted by them because of our strength and our mature contributions to the technological life of our nation.

* Excerpts from an address to the 8th Annual Convention of AIIE, New York City, May 18, 1957.

Our Dynamic World

The world of engineering is a constantly changing kaleidoscope of problems and solutions. The man who wishes merely to become a disciple of past practice is missing the most interesting and important phase of our real purpose as Industrial Engineers.

In the future, Industrial Engineers must be prepared to enter into many of the larger decisions which must be made to determine the prospective course of an enterprise. The narrow outlook toward Industrial Engineering is no longer valid.

Yet the changing face of any dynamic field sometimes obscures the unchanging fundamentals upon which that field rests.

Engineering, broadly, is supported by a tripod foundation. The legs of this tripod are:

Energy
Manpower
Materials

in alphabetical order. But the most neglected leg of the tripod is the one in which Industrial Engineering has the greatest interest:

Manpower.

It will be seen that the various branches of engineering place special emphasis on different legs of this tripod foundation. For example, electrical engineering is heavily slanted toward energy, metallurgical and civil engineering toward materials, and mechanical engineering divides its

attention between energy and materials. Industrial Engineering, alone, concentrates heavily in understanding, utilizing, and controlling manpower. The real challenge to us is to understand the effect of current and future forces upon the utilization of manpower. We must not lose sight of the fact that men must be treated as individuals, if successful utilization is to be achieved. No man wants to be a statistic.

The Team Approach

There has been an unfortunate dichotomy in our profession between those who look ahead and those who wrestle with our important day-to-day problems and frustrations. A good deal of mutual suspicion has passed between the groups. The dreamers, the thinkers, and the planners are prone to call the daily practitioners stodgy and unprogressive, while their opposite numbers are regarded by the practitioners as impractical, unrealistic, and illogical. Both groups are wrong in their appraisals of each other.

This is a world in which the probability of a significant contribution from an individual genius is less than the probability of great discovery and advancement achieved through a team of specialists pulling together in harmony. There is ample opportunity in the team approach for individual opinion and discussion. Moreover, the power of many minds of diverse attributes, working toward a common goal, cannot be defeated. I hope such power will be clearly evident as we in AIIE attack and solve our future problems.

Applied Sciences in Industrial Engineering

Engineers today must be scientists with a sense of urgency. We must utilize all of the new tools at our command in building our professional world and in solving our problems.

For example, game theory, linear programming, and Boolean algebra all have their specific contributions to make to our knowledge, as does applied psychology. These must be brought into focus as understood techniques, so that they may be reduced to practice. Furthermore, fundamental research in the scientific bases underlying Industrial Engineering must be expanded to bring to light new principles which may be converted into tools of analysis for the Industrial Engineer.

At this point some will ask if we aren't being just "faddy." They will question whether "common sense," after all, isn't the common platform under all engineering applications. They think they see much charlatanism in all of the more recent areas of development, such as operations research, but fail to see the great numbers of dedicated thinkers who now are building toward an Industrial Engineering science which we must have to cope with the multitude of complex problems in the future. Many of the thinkers also have erred in their failure to place men on their teams from the hard-headed practical areas of modern Industrial Engineering practice. These two factions must be taught to communicate effectively, and, indeed, to coordinate their knowledge to productive ends.

The Need for a Changed Approach

Many will ask why Industrial Engineers must change their approach. "Why aren't our proven empiricisms good enough?" they ask.

In framing the questions, they fail to recognize the changing complex of industry.

A short few years ago, a mistake in specifying a given machine was readily absorbed by the industrial system. Its cost was a minor fraction of total invested capital. But today an automated line may require a substantial proportion of the available capital of a company. A mistake in prognosis or design can be fatal. We therefore live in an era wherein much more accurate predictions must be made by Industrial Engineers, if proper guidance is to be provided to a corporate management. And we must be prepared to accept larger responsibilities.

High minimum wages, generally favored by all, require reevaluation of our parameters for plant design, and of our employment practices. The accompanying squeeze on wage and salary scales places great stress upon accurate standards for production. These standards can be developed only through the proper use of our newly applied statistical tools, which we must use more vigorously in the future.

The guaranteed annual wage places considerably more emphasis on an area formerly ignored by the Industrial Engineer: sales prediction. Corollary to this is the need for much more accurate scheduling and programming in a plant. Gone is the day when overstaffing for peak loads was an economic system for supplying customer needs. To control production the Industrial Engineer must have accurate sales estimates and selling rates at his disposal. And if these are not available he must concern himself with the problem of developing such necessary data.

Modern tooling costs are so high that the prediction of the production life of a given model assumes gigantic proportions. Without high production quotas, today's automotive tooling would be impossible. This, too, emphasizes the need for greater accuracy of prediction.

The Personal Equation

This is an age of bigness. Mergers are all around us. And such movement increases the use of impersonal systems in which individuality is lost.

Industrial Engineers who are sensitive to the need for appreciation of the individual, and who establish systems which are personal rather than impersonal without departing from statistical soundness and proper accuracy, may well make the greatest single contribution to proper worker motivation in the last two decades. A consideration of people as individuals is rapidly becoming essential to the establishment of sound industrial control systems.

Relentless Search for Truth

There are so many tensions in our modern industrial complex that opinion often becomes a substitute for fact, and subjectivity rather than objectivity dictates decisions.

Tensions between management and labor, between sales and manufacturing, between manufacturing and engineering, between line and staff, are all too common. What is the solution? An understanding of the underlying forces at work, and the development of a sensitive detection system will provide early warning before internal conflict destroys the industry team. This, too, is the work of the Industrial Engineer. And the solutions will be found only through the tireless seeking of truth in the welter of subjective argument, and the establishment of criteria which can guide the proper management of the corporation team.

In the search, realism must never be lost. An idealistic model stripped of all practical complexities may aid materially in understanding such problems, but it is virtually meaningless in effecting a solution. Here again, practitioner and theoretical scientist must work as a team.

Our Organization—Its Destiny

We have an every-member task. Each member of AIIE, working in unison with his colleagues on the problem areas in which he has the greatest experience and has done the most incisive thinking, can contribute to our ability to achieve accurate methods for predicting future trends, and for dynamic . . . rather than oppressive . . . control of current operations.

Let's make 1957-58 the year of consolidation, continued growth, and professional maturity. But above all, let's make it a year of new awareness of the larger task of Industrial Engineering in the decade ahead.

With teamwork we cannot fail. Without it we cannot succeed.

INSTITUTE INTERESTS

CALENDER

July 8-10: Third Annual Creative Problem Solving Institute; The University of Buffalo, Buffalo, N. Y. Write Dr. Sidney J. Parnes, Director of Creative Education, The University of Buffalo.

August 19-30: Short Course in Management Science and Computer Technology; University of Michigan, Ann Arbor, Michigan. Write Richard C. Wilson, 2038 East Engineering Building, University of Michigan.

September 5-13: Third Annual Intensive Course in Statistical Quality Control; Sever Hall, Washington University, St. Louis, Missouri. Write J. K. Lahr, University College, Washington University.

September 24-25: Sixth Annual Industrial Electronics Symposium; Morrison Hotel, Chicago, Illinois. Write H. L. Garbarino (AIEE), Armour Research Foundation, Illinois Institute of Technology, 10 W. 35th St., Chicago 16, Illinois.

PERSONALITIES

Phil Carroll

On March 18, 1957, Phil Carroll made full payment on a Life-Status Membership under a by-law to the Constitution approved in October, 1956. Mr. Carroll made payment of $376.50, and thus became the first member to take advantage of a Life Status Membership.

Harold T. Amrine

The Material Handling Institute, Inc. has named Harold T. Amrine as 1957 chairman of the College Industry Committee on Material Handling Education. Amrine is Head of the Department of Industrial Engineering at Purdue University. The College-Industry Committee is part of the Institute's program of assisting with the development of material handling education programs at the college level and in extension courses. Committee activities include development of visual aids, course outlines and coordination of research projects.

Grant Ireson

A joint Industrial Material Handling and Packaging Conference, co-sponsored by the San Francisco Chapters of American Material Handling Society and Society International Packaging and Material Handling Engineers, and Stanford University, was held at Stanford on March 29 and 30. The 2-day conclave featured experts from the Bay area conducting discussion groups on problem subjects. Professor Grant Ireson, Head of the Department of Industrial Engineering at Stanford, delivered the keynote speech.

Joseph Terr

At the March meeting of the Cleveland Chapter of AIIE, Mr. Jospeh Terr, was awarded the National Award for designing the AIIE insignia. Mr. Terr, a consulting engineer and industrial arts designer, does considerable lecturing, writing, and holds numerous patents on illumination equipment, ultraviolet appliances, and other products. His affiliations include: The Illuminating Engineering Society, Society of Professional Engineers, American Institute of Industrial Engineers and Cleveland Technical Society Council.

ATLANTA CHAPTER

The January meeting was held on January 29 at Western Electric Company. The automatic order picking material handling system was the major item of interest during the tour of the plant. After dinner in the company cafeteria two movies were shown of Western Electric operations. The AIIE Georgia Tech Student Chapter members were special guests at this meeting.

The February meeting was held February 26. Mr. L. W. Miller, Management Consultant of Arthur Young and Company, of Los Angeles, spoke on the need for accounting techniques as well as engineering skills for effective control methods.

The March meeting was held March 26. Dr. Joseph Krol, of Georgia Tech, spoke on "Some Aspects of New Product Development". His talk emphasized the importance of the evaluation phase of new products and that industrial engineers were particularly well qualified to aid in this evaluation.

The April meeting was held April 23. Mr. Frank J. Johnson, Manager, Production Engineering Design Analysis, Lockheed Aircraft Corporation, Marietta, Georgia, spoke on "The Role of Industrial Engineering in Product Design".

The following officers were elected: Milt Pitts, President; John Scott, First Vice President; Bill Parks, Second Vice President; Martin Roberts, Secretary; Mark Balcom, Treasurer; Dan Mahaffey and Jack Walker, Directors.

This chapter again sponsored an Industrial Engineering Refresher Course to help engineers prepare for the State Board Examination. This year, as in the past, it was held on the Georgia Tech Campus on these dates: April 27, May 4, May 11, May 18 and May 25.

CHICAGO CHAPTER

"At our April meeting, which was held on Tuesday, April 9, at the Western Society of Engineers, the subject matter centered on "Work Sampling". The speaker for the evening was Wallace J. Richardson, Associate Professor of Industrial Engineering, Lehigh University, Bethlehem, Pennsylvania. This discussion was designed to give a practical application of the technique to those attending. Professor Richardson is a graduate of the U. S. Naval Academy with an M.S. in Industrial Engineering from Purdue. He has taught at Lehigh University since 1952, has conducted Work Sampling studies in a wide variety of industries, and is co author of a book on the subject published by McGraw Hill this April. Professor Richardson brought the following aspects of Work Sampling before our group:

1. Methodology—how to conduct a Work Sampling study.

2. Reliability measures—how to use elementary statistics to appraise the usefulness of results.

3. Control Chart concept—how to use results of Work Sampling to effect improvement.

4. Examples—from shop, office, materials handling, drafting room, merchandising, and the determination of work measurement allowances.

CLEVELAND CHAPTER

The regular monthly meeting was held at the Cleveland Hotel on Thursday, April 4, at 8:00 p.m. The subject, "To Simplify or Not To Simplify", was presented by Don F. Copell, Vice President, Wagner Baking Corp., Newark, New Jersey. Mr. Copell has won international acclaim for his distinguished contributions to the Industrial Engineering field. He is a recipient of the Gilbreth Medal and many other awards for outstanding service in this profession. One of his pet subjects is "Work Simplification", an area in which he has done considerable research.

On April 18, the Chapter sponsored a plant tour of the Nela Park Lighting Institute. After gathering in the lobby of the Lighting Institute Building, the group was privileged to: tour a home to see the latest in lighting effects; observe office and school lighting techniques; see "live" from the stage of the Lighting Institute a demonstration entitled "Lighting the Way"; and visit the lamp gallery.

DAYTON CHAPTER

The April technical session of the Dayton Chapter was held at the Delco Products Division Auditorium on Tuesday evening, April 9. The subject of the evening was "Management Looks at the Industrial Engineer". Mr. Clem Ruhl, General Superintendent, Standard Register Co., presented this topic. The purpose of this session was to provide the industrial engineer with an objective appraisal by management of the role that the I. E. plays in an organization, his present and potential value, his channels for development, the kind of I. E. needed in the future and where he will "fit", and some self improvement suggestions. Mr. Ruhl, who was at the management level when industrial engineering was in its embryonic stages, has had the opportunity to observe its growth and value to an industrial organization.

HOUSTON CHAPTER

The Houston Chapter's first program of the 1956-57 season was a presentation in September on "Problems in Plant Layout" by Mr. W. A. Langdon, Plant Engineer of Mission Manufacturing Company. Mr. Langdon gave a very interesting and informative case history of considerations raised and the problems and opportunities encountered when his plant initiated a detailed study of a proposal to move to a new location.

The subject of the October Meeting was "Industrial Engineering at Hughes Tool Company." Mr. R. W. Wendenmeyer, Chief Industrial Engineer, was assisted in a three part presentation by Mr. S. A. Brooks and Mr. J. Z. Brewer. Mr. Wendenmeyer presented the philosophy, scope, standing assignments and objectives of Industrial Engineering at Hughes. Messrs. Brooks and Brewer presented specific cases to illustrate parts of Mr. Wendenmeyer's discussion. The program was well received by members and guests at the meeting.

The Second Annual Work Measurement Conference, held in November, was our next meeting. Five outstanding speakers presented papers on the following important topics:

Indirect Labor Standards—Mr. Gerald Lowendick, Supervisor of Work Standards, General Motors Corporation, Arlington, Texas.

Administration of a Work Measurement Program—Mr. H. C. Snyder, Chief Industrial Engineer, Texas Electric Steel Casting Company.

Human Relations Aspects of Work Measurement—Dr. A. Q. Sartain, Professor of Psychology, Southern Methodist University.

New Techniques of Work Measurement—Dr. R. N. Lehrer, Professor of Industrial Engineering, Georgia Institute of Technology and Editor, Journal of Industrial Engineering.

Work Measurement in the Overall Control Program—Dr. Raymond Villers, Consultant in Industrial Management, Rautenstrauch and Villers.

The conference was highly successful. As in the First Conference, subject matter of the Second Conference was used to good effect as the basis for an editorial in the Houston Chronicle. We believe these conferences are indirectly serving to inform the general public of some of the more interesting aspects of Industrial Engineering.

At the December Meeting Mr. W. J. Bentley, Professor of Industrial Engineering, Oklahoma A & M and Regional Vice President of AIIE, spoke on "The Internal Consulting Functions of the Industrial Engineer". His audience found the presentation very interesting and worthwhile. The highlight in his talk was a demonstration from an actual case of how differently the various members of top and middle management visualize the organization, areas of authority, responsibility and activity. We might find it both revealing and beneficial to most of us if we would have each important member of Management in our own organizations sketch his mental picture of the organization.

JACKSONVILLE CHAPTER

The Jacksonville Chapter held its April meeting on Thursday, April 11, 1957, at the Mayflower Hotel. The speaker, Mr. Carl John, Management Consultant, Ernst & Ernst, Cleveland, Ohio, presented a very stimulating talk on "Engineered Performance Standards and Standard Costs".

LOUISVILLE CHAPTER

At our February meeting, Mr. Frank M. Thompson, an Associate in the New York Office of McKinsey & Co., Inc., Management Consultants, addressed a select group of members and guests on "Management Training in the Factory".

Dr. Marvin E. Mundel, Vice Director, Management Center, Marquette University, Milwaukee, Wisconsin, was guest speaker at the March meeting. The subject of his address was "Objective Rating."

The program for the April meeting at the Kentucky Hotel was on the subject of "Methods Time Measurement." Mr. Donald G. Stohlman, Executive Vice President, New York Office, Serge A. Birn Co., Inc., presented this interesting program.

MEMPHIS CHAPTER

Our March meeting was held on March 27, 1957, the last Wednesday of the month at 8:00 p.m., Poplar Plaza Branch, First National Bank. The program featured a lecture by our Program Chairman, Bud Balkin, on the application of quality control to complex items such as guided missiles.

Our attendance in February was rather small, but after the film program we all got into a bang up round table discussion minus the table.

MIDDLE TENNESSEE CHAPTER

The March meeting of the Middle Tennessee Chapter was held at the AEDC Officers' Open Mess in Tullahoma. Three speakers highlighted this meeting. Thomas Bigger presented a brief resume of a talk by Phil Carroll given in Nashville recently; Wendell Graddy, president of the Tullahoma Chapter, gave a report on highlights of the fourth annual conference of the Southeastern Region AIIE, which took place in February at the University of Tennessee; and feature speaker of the evening was Miles Maynard, director and constitution chairman of the AIIE, Middle Tennessee chapter. His topic was "Creative Thinking", and included a demonstration of "brain storming".

Members of the Middle Tennessee Chapter, American Institute of Industrial Engineers went to Nashville Monday, April 29th, for the regular monthly meeting of the organization. Meeting time was 6:30 p.m. at Peggy Wales' Restaurant. Coffee County members were guests of a group of engineers from the Nashville area. General theme and purpose of the meeting was "Expanding AIIE in Middle Tennessee".

PHILADELPHIA CHAPTER

Before the largest turnout of the season, the Philadelphia Chapter presented a moderator panel discussion on "Problems of the Industrial Engineering Administrator" as the subject of its March meeting. The moderator was Mr. T. A. Nupp, Chief Industrial Engineer, Sealtest Supplee Division, National Dairy Products Corporation. The panel members were Mr. C. Anderson, Manager of Manufacturing Placements Division, Buttrick & Megary; Mr. A. Chapman, Chief Industrial Engineer, Philco Television Division; Mr. R. H. Knoble, Manager, Industrial Engineering Division, Brown Instruments Division, Minneapolis-Honeywell Regulator Company; and Mr. R. L. Utz, Chief Industrial Engineer, Martin Century Farms, Inc.

Among the topics which the panel covered were the purpose of the Industrial Engineer and the Industrial Engineering Department, place of Industrial Engineering in the organization and its relationship to other areas of the company, organization of the Industrial Engineering Department, and criteria of performance for the Industrial Engineer and the Industrial Engineering Department.

It was generally agreed that the primary function of Industrial Engineering is the control and reduction of costs. The Industrial Engineering Department should report to as high a level of management as practical. The actual place of Industrial Engineering in the organization of each company will differ depending on the nature of the product, methods of manufacture, type of industry, etc.

It was pointed out that the Industrial Engineer will be able to do a better job if he is willing to recognize that Industrial Engineering is primarily a staff function. Above all, the Industrial Engineer must be a good salesman if he is to do his job properly. The problem of salesmanship and the ability to get along with others is even more acute at the administrative level. It is extremely important to keep management informed of the objectives and progress of the Industrial Engineering Department.

The annual business meeting of the Philadelphia Chapter was held in April. The following officers were elected for the 1957-58 season.

President	Frederick A. Cline, Jr. Division Head, Industrial Engineering Department Leeds & Northrup Company
Vice President	Thomas A. Nupp Chief Industrial Engineer Sealtest Supplee Division National Dairy Products Corporation
Secretary	Richard W. Walton Senior Industrial Engineer Merck Sharp & Dohme Division of Merck & Co., Inc.
Treasurer	Virgil J. Diana Methods Engineer Leeds & Northrup Company

PHOENIX CHAPTER

A meeting was held on October 23, 1956 at which eight Industrial Engineers professed an interest in initiating a chapter of the AIIE in Phoenix. These individuals organized a steering committee under Mr. Forrest Smith, Arizona Products and Machinery Company, to guide the organization.

On November 27, 1956 a dinner meeting was held to discuss the formation of the chapter. Forty engineers participated in this meeting and committees were appointed to plan for the next meeting and to prepare a constitution for the chapter.

A "work" meeting was held on December 18, 1956 at which the constitution was adopted and plans for the coming year were discussed.

At a dinner meeting on January 22, 1957, Mr. Lew Haas, Executive Secretary of the Phoenix Chamber of Commerce, welcomed the organization to Phoenix and discussed the "Past and Future of Industry in Arizona."

The February meeting was held on the 26th at which Mr. Herbert Grosch, Director, Computer Applications, for General Electric Company in Phoenix, discussed the effects of computers of industry and the need for Industrial Engineers to know and understand the automated data processing.

The Constitution of the Chapter was approved by the National Organization on February 25, 1957.

Election of permanent officers for 1957 was held in February and the following individuals were elected:

President	Raymond A. Nelson	Reynolds Metals Co.
Vice President	George Beakley	Arizona State College
Secretary	John Noonan	Reynolds Metals Co.
Treasurer	Emil C. Karas	Goodyear Aircraft Corp.
Directors	Merle Nutt	Arizona State College
	Bart Albright	Consulting Engineer
	Marvin G. Rice	Motorola, Inc.
	Robert Lidington	Goodyear Aircraft Corp.
	Donald Teapole	Reynolds Metals Co.

Meetings are held on the fourth Tuesday of the month at the Desert Hills Hotel with a social period between 6:30 and 7:00; dinner is served between 7:00 and 8:00; and the official meeting is from 8:00 to about 9:30.

The meeting held on March 26 was the formal chartering meeting. Mr. Jim Nordahl, Vice-President of the Western Region of the AIIE, presented the charter. Mr. Walter Lucking, President of Arizona Public Service, was the speaker of the evening.

ST. LOUIS CHAPTER

The February meeting, which took place at Ruggeri's Restaurant, was under the chairmanship of Prof. D. J. Kaufman of Washington University. Mr. William R. Vogel, Dept. of U.S. Army Ordnance Corps., spoke on Mathematical Programming. Mr. Vogel presently holds the position of Programming and Statistics Specialist for the Ordnance Management Engineer Training Program, U. S. Army.

In March, Mr. C. E. Heitman, President of Carter Carburetor, Division of ACF Industries, Incorporated, spoke on the highly important subject, "The Boss Communicates". This meeting was held in the Regency Room of the Hotel Chase, with Mr. C. G. Downen, Perceptual Development Laboratories, White-Rodgers Electric Company, St. Louis, acting as chairman.

The St. Louis Chapter has completed election of officers for the 1957-1958 term. President for the coming year is Martin Bauer, Assistant Chief Engineer of Carter Carburetor—Division of ACF Industries. Mr. Bauer served last year as Vice President and in recent months has been President pro tem of this chapter. Vice President is Owen Miller of Washington University. Secretary is W. Bernard Saunders of American Car and Foundry Division of ACF Industries, and Treasurer is Charles S. Wicks of Chase Bag Co. Elected to two year terms as members of the Executive Committee are A. B. Drui, Dow Chemical Co.; Herbert R. Richter, Cupples Products Corp.; and Ernest H. Walker, Granite City Steel Co.

This Fall the Industrial Engineering Department and the University College of Washington University will present their third annual intensive course in Statistical Quality Control. The course is being offered in cooperation with the St. Louis chapters of the American Society for Quality Control, American Institute of Industrial Engineers, and the Society for the Advancement of Management. The dates for the course will be 5 September through 13 September. Meetings will be held in an air conditioned room in Sever Hall on the Washington University campus. This course is primarily intended for personnel in industry desiring a basic introductory course in statistical quality control. Emphasis will be on the techniques of application rather than fundamental theory, although the necessary background material will be presented. The objectives of this course will be the preparation of the students for the application and administration of quality control in their own industry. Enrollment is limited to the first 25 registrants. For further information about enrollment, fees, and a descriptive program write to University College, Washington University, St. Louis 5, Mo.

RECENT READABLES

AUTOMATION

"How Can Offices Meet the Rising Costs of Production," by H. L. Wylie, *The Office*, p. 77, March 1957.

The increasing use of mechanical equipment as a means of stemming the upward spiral of office costs has caused many potential buyers to turn to the rental path for the use of the equipment. Almost all mechanical aids to production are available through lease—it is only a matter of determining the mechanics of the leasing method and the terms. The prudent company avails itself of all mechanical aids to increased productivity without waiting until the acquisition can be accomplished by traditional budgetary appropriations. The pay out period, in which the savings are greater than the added cost, is or should be the guiding principle of mechanization.

"Office Automation—How Far Have We Come Today," by Editors, *Office Management*, p. 27, Feb., 1957.

This well written article is definitely of interest to every person involved with automation in any phase of business operations.

The authors state "that Automation is more than mere mechanization of existing routines. It is recognized that it makes obsolete many existing procedures. But is it possible that it also makes unnecessary many of the end results always before considered essential?

Many businesses have "automated" through design and installation of a new system and new machines to speed and make more efficient their regular work flow. But how many have thought of automation as itself a system; how many have applied the key point of automation theory, "feedback," within their own operating routines to derive the fullest advantage from the new concept?

Before automation can be fully exploited, many traditional accounting and reporting standards will have to be analyzed and revised.

GENERAL

"Designing with High Speed Computers," by L. S. Linderoth, Jr., *Machine Design*, p. 72, March 7, 1957.

Electronic and mechanical computers, both large and small, have been used for many years in scientific computations and certain areas of engineering. In recent years, there has been an increasing awareness of the usefulness of these machines as an aid in design. High speed, automatic electronic computers make possible more rigorous analyses of strength and performance of machine elements and assemblies. As a result, optimum designs are usually determined easier and faster than by rule of thumb practices.

This article summarizes considerations in using computers in design and presents a number of typical problems in which computers can be applied.

"Engineering Writing," by G. A. Cederborg, *Machine Design*, p. 80, March 7, 1957.

Technical writing can be pruned of gobbledygook as easily as drawing a fillet, and this will clarify it as much as a fillet strengthens a corner. All that is needed is editing according to danger-signals.

Redundancy, indecisiveness and other danger signals are discussed in this article. Each category is represented in the check list containing examples of poor writing commonly

found in technical literature. This check list will assist in editing a manuscript or draft.

"How to Make Your Forms Simple, Effective, Economical," by George Bick, *Office Management*, March, 1957.

Individually, office forms cost very little, the author says, but collectively they represent a heavy company expense. This article describes ways to keep the cost of forms as low as possible by utilizing the most efficient processes for composition and presswork and gives some useful tips on preparing forms and specifications, devising numbering systems for forms, and issuing instructions for the use of the completed forms.

"How Well Do You Write?", by S. D. Boynton, *Petroleum Processing*, p. 75, April, 1957.

This article contains an analysis of what's wrong with technical writing and how to improve it. The author has taken leading ideas, added some of his own experience with technical writing, and organized this quick reading survey.

Though it's no secret that much technical writing is poor, some further evidence from the oil industry was offered at a recent meeting of an American Chemical Society group. Two men from Esso Research & Engineering Company discussed a study of recent technical school graduates and their supervisors. The subjects were in the research company and in Esso Standard Oil Company. The "greatest weakness" of the young technical men, according to 45% of their supervisors, was in letter and report writing.

The author suggests these keys to good writing:

1. Think before you write.
2. Make an outline.
3. Follow the natural logic.
4. Write crisp sentences.
5. Use short, familiar words.
6. Put conclusions at the start.
7. Don't be a stickler for grammar.
8. Use active verbs.
9. Consider your reader's interest.
10. Take pride in clear writing.

"Light for Industry: A Neglected Production Tool," *Manufacturing and Industrial Engineering* (1940 Don Mills Road, Ontario, Canada), Jan., Feb., 1957. $4.00 a year.

A discussion of the factors of good illumination, both natural and artificial, and the criteria for judging it. Illustrated with examples taken from Canadian industrial firms, this section is designed to assist manufacturers in raising productivity, morale, and efficiency through the most effective use of lighting. Included is a useful chart of the levels of illumination recommended for various types of tasks.

"New Frontiers for Packaging," by Editors, *Modern Packaging*, p. 22, May, 1957.

In the past year, packaging has made great progress in two directions: 1. the removal of more and more work from the packaged product before it leaves the factory, and 2. greater display impact and improved self selling efficiency.

Looking ahead, it seems likely that there will be important new contributions to these aims this year, including:

New types of laminations and coatings.
More multi unit packaging.
Further improvements in color printing and color control.
Broader applications for aerosols.
Greater packaging use of aluminum in many forms.
Lighter weight glass.
Further functional improvements in cans.
Big volume use of throw away molded and formed plastic packages.

"Operational Approach to Creativity," by J. J. Gordon, *Harvard Business Review*, p. 41, Nov., Dec., 1956.

Creativity is like peace: everyone wants it, everyone seems to have some ideas about it, but nobody appears able to produce it. Consequently, the businessman is beginning to wonder whether this is all a pipe dream or, at best something that "just happens" like a good poker hand.

The author has worked out a new approach which is designed to accomplish two objectives: enable the executive to stimulate creativity and help the researcher to find out something about it. His article is a discussion of the business-oriented side of his study. It includes some practical advice to the business manager, and features a transcript of actual group creativity sessions, with interpretative comments by the author.

"The Ten Biggest Pitfalls in Plant Location," by L. C. Yassen, *Dunn Review and Modern Industry*, p. 49, March, 1957.

In a survey conducted during the past three years, more than 1,000 major industrial firms have been asked: "Has your new plant location been completely successful and, if not, what have been the most important contributing factors?" Their answers to this question were compressed into a list of the ten most common and costly mistakes.

These are the principal mistakes made by those whose moves have not worked out as they anticipated:

1. Miscalculation of labor costs.
2. Choice of site where the labor reservoir is inadequate.
3. Neglect to anticipate growth.
4. Carelessness in checking the site.
5. Lack of distribution know-how.
6. Failure to predict the impact of the new plant on the community.
7. Neglect to check on supporting facilities.
8. Reliance on misinformation on utility costs and problems.
9. Understanding the importance of taxes.
10. Failure to recognize cost relationships.

"Top Management Decision Gaming," *The Management Review*, p. 46, May, 1957.

An original approach to the problem of simulating the decision making process is Top Management Decision Gaming, a training device just developed by the American Management Association. Basically, it is a business "war game" in which teams of players, in direct competition with each other, make the basic decisions of the kind that face every top management and see the results immediately. The game is specifically designed to provide conditions under which a few hours of concentrated decision making under pressure will simulate years of business experience.

The key to the game is a mathematical model of business, a group of cause and effect formulas that would determine the results of each move made by the players.

The model, developed over the course of a year, has been changed half a dozen times in the course of various test runs. Results were originally computed on desk calculators. Later the game was programmed on the IBM Type 650 electronic computer.

INVENTORY CONTROL

"Inventory is Kept More Accurately and Cheaper by Machines," by J. H. Leach, *The Office*, p. 118, April, 1957.

In any manufacturing company, a fundamental part of production control and planning consists of comparing the allocation of raw materials against the actual usage of such materials, for any given manufacturing process. Unless the

planned and actual usage are compared continuously, there can be no real control over production, and no accuracy in determining standard material amounts for standard products. There is also the ever present problem of controlling the actual raw material inventory.

The Upjohn Company has been successful in combining raw materials allocation versus usage, and actual inventory, on the same ledger card. A machine method of posting the information insures the absolute accuracy essential to both phases of the system. Approximately 35,000 postings are made each month to about 3,000 ledger cards.

OPERATIONS RESEARCH

"Capital Budgeting and Game Theory," by E. G. Bennion, *Harvard Business Review*, p. 115, Nov., Dec., 1956.

Among the newer techniques available to managers is the so called "theory of games."

The author sheds some light on one of the thorniest problems in business management—capital budgeting. He is concerned especially with relationships between the budget and the general economic forecast which must underlie it. His description of game theory in action at this crucial point of management planning is designed to stimulate thinking as to other applications within other companies.

"Operations Research," by L. C. Lockley, *Conference Board Reports No. 82*, published by National Industrial Conference Board.

Operations research is an analytic approach, depending on team or group research, which was adapted to the study of military problems during World War II. It is essentially a method of studying the operation of a system or an integrated set of actions.

It usually employs the talents of a variety of specialists, utilizes mathematical analysis, seeks underlying principles, and brings in conclusions which indicate the probable results of various courses of action. The conclusions of an operations research study are likely to be shown as a range of alternate possibilities, rather than as a single "right" answer.

Its most useful application is to complex problems where many factors are involved and where the elements of the problem can be measured and described in quantitative terms.

"The Simplex Method for Solving Linear Programming Problems," by C. E. Noble, *Industrial Quality Control*, p. 5, March, 1957.

Linear Programming is a method for optimizing a linear function when the variables are subject to a set of linear constraints. There is a wide range of problems solvable by linear programming methods, particularly in the area of scheduling production and shipments. Even though the basic theory for solving these problems has been known for many years, it has been only during the past ten years that practical methods have been developed. The "Simplex Method" is the most general of these methods.

This article shows how the simplex method is applied in solving two industrial problems.

"Thoughts on Linear Programming," by G. B. Dantzig, *Management Science*, p. 131, Jan., 1957.

Mechanization's purpose is to relieve man of certain duties using human energy for power; automation's purpose is to relieve him of certain mental tasks and the related physical tasks necessary for their expression. Electronic computers, which are themselves examples of automation, will play an important role in the mechanization of control processes of the routine type.

It is generally conceded that "higher level decisions will be made by man primarily because he, through the exercise of his mind, possesses the only means of integrating data for which rational formulations are not yet possible or are too expensive.

Even in the realm of higher order controls, particularly those mental tasks involving selection from among alternative courses of action, this too is undergoing mechanization.

Through programming—defined as a schedule of actions by means of which an economy, organization, or other complex of activities, may move from one defined state towards some defined objective—and their physical realization known as production control. One senses the important role that electronics computers will play.

It is possible that the mechanization of certain of the more complex control processes are really the beginnings of an age of "super automation."

The logical steps in this development might be:

1. Mechanization: Machines replace human energy tasks.
2. Automation: Machines replace simpler human control tasks.
3. Super Automation: Machines replace complex human control tasks.

QUALITY CONTROL

"New Multiple Sampling Plan for Quality Control," by Richard M. Jacobs, *American Machinist*, Feb. 11, 1957.

This article describes a cost-savings system for administering multiple sampling inspection, which the author believes is the most economical of all the commonly used sampling techniques. He tells how more efficient quality control can be achieved through the use of explicit inspection instructions, standard weighting factors, and accurate records of recurring defects.

"The Ampex Quality Rating System," by R. L. Pappas, *Industrial Quality Control*, p. 9, March, 1957.

Recently initiated within the Ampex Corporation is a new system for evaluating the quality levels of products at their various stages of fabrication. This article presents in three sections the background resulting in the development of the system, a description of the system itself, and the mathematical and statistical theory relating to the functioning of the system.

WAGE AND SALARY ADMINISTRATION

"Plan for Management Salary Administration," by R. E. Sibson, *Harvard Business Review*, p. 102, Nov., Dec., 1956.

Though a relatively young man, the author has had considerable training and experience in the field of personnel and industrial relations.

He became interested in this field after he found that salary relationships among management people were, in fact, less logical than among clerical or hourly people. Invariably, management recognized the problem, but it seemed at a loss to take appropriate action to correct the situation.

On the basis of his own experience and his observation of other companies the author establishes some criteria for a management salary structure, provides a check list for a job evaluation plan, presents some sample job descriptions, and sets forth the necessary administrative procedures.

WORK MEASUREMENT

"Physiological Study of Motions," by L. Lauru and L. Brouha, *Advanced Management*, p. 17, March 1957.

The author states that from Taylor to Bedeaux and MTM, valuable attempts have been made to improve work. Working standards and rhythms have been established and studies of the psychological aspects of the problem are progressing. But the fundamental question has not been adequately tackled

because no measuring method has taken into account the basic and irreducible core of the physiological possibilities of the human machine.

The authors' method involves an analysis of both mechanical forces and energy expenditures involved with each job.

The analysis of mechanical forces is accomplished through use of a specially designed platform which measures the sum of dynamic forces involved in a motion.

Energy expenditures are measured by indirect calorimetry based upon the average calorific value of the oxygen consumed.

Industrial applications of the technique included are: brick laying, grinding, textile spinning, cutting and stamping, welding and clerical work.

BOOKS

Scientific Inventory Control, by W. E. Welch, 158 pp., Management Publishing Service, 22 West Putnam Ave., Greenwich, Conn., $12.50.

This book effectively bridges the gap between elementary industrial practices and advanced techniques of operations research and linear programming applied to inventory control. The scientific determination of the two factors affecting inventory; "how much" of an item is to made or purchased; and "when" it is to be made or purchased, is developed. Order Quantity formulas and Reorder Point formulas are presented and discussed, with calculations of variables explained. Calculus is judiciously avoided and only a minimum of high school algebra is used. The advantages of scientific inventory control versus intuitive control are discussed in terms effectively designed for the typical executive involved with the administration of the inventory function.

Installation Manual—Universal Plan of Job Evaluation, P. A. Belanger (self published—1956), P.O. Box 63, York, Pa., $10.

This publication is concerned exclusively with the mechanics of a job evaluation plan developed by the author and intended to apply to the evaluation of *any* job in any business. Divided into two parts: "Job Evaluation" and "Merit Rating of Employees," plus a general preface and an appended collection of copyrighted forms tailored to the system.

Part One describes the mechanics of the evaluation system and explains how to apply them. The plan itself is based on the standard point method of evaluation with a total of eleven factors, five of which have two parts to each with one part applying to jobs involving manual effort primarily and the other to jobs involving mental effort primarily.

Part Two covers merit rating in order to provide a method of personnel evaluation and thereby complement job evaluation if pay brackets are used instead of fixed rates.

I. E. OPPORTUNITIES

WHAT IT IS

The industrial engineering opportunities service is a functional committee of the American Institute of Industrial Engineers which collects information concerning employment opportunities on a nationwide basis and provides this information to members upon request. The committee is composed of members from the Columbus, Ohio chapter and the information is furnished free as a service to industry and Industrial Engineers.

SERVICES PROVIDED

Some of the known job openings will be published in condensed form in each issue of the Journal of Industrial Engineering which is issued bi monthly to over 6,000 members and student members of the AIIE.

In addition, a monthly I. E. Opportunities Bulletin is supplied to over seventy chapters located throughout the United States.

Each job opening is assigned a "P" number for identification. The name and address of the person to contact for additional information concerning a specific job opening is sent to members on request.

ADDRESS OF THE SERVICE

I. E. Opportunities Service
American Institute of Industrial Engineers
145 North High Street
Columbus 15, Ohio

EMPLOYERS

Employers having openings for qualified Industrial Engineers are invited to list them with the Industrial Engineering Opportunities Service. Government agencies and educational institutions as well as business and industry are urged to take advantage of this free service. By publicizing your job openings with our Institute, you are sure of reaching high calibre men who have passed the Institute's strict membership qualifications and are fully qualified to fill many types of Industrial Engineering jobs.

Industrial Engineers are often employed in such fields as Work Measurement, Production Control, Plant Engineering, Operations Research, Industrial Relations, Sales, and Management. For a more complete coverage, see the following list of job classifications. Please do not hesitate to forward information on jobs in any area where it is recognized that an Industrial Engineering background will be of value.

To list your job openings with the Opportunities Service, send all or part of the following information with the name of your contact man to the above address: Type of industry, location, job classifications, minimum educational and experience qualifications, and salary range.

This information will be publicized to the members in condensed form in the Journal and in monthly chapter Bulletins. Company names are not shown. Should you desire a large ad elsewhere in the Journal, advertising rates will be quoted upon request.

MEMBERS SEEKING JOB OPPORTUNITIES

The following list shows job openings available on June 1, 1957. If you would like more information about one or more of the positions listed, mail the "P" numbers with your name and address to the Opportunities Service at the above address. The Service will advise you by return mail of the name and address of the person to contact for further information, or advise you if the position is no longer available. Your name will not be forwarded to the company with the job opening so you must take the initiative yourself.

For more current listings, contact your local Chapter Secretary or Opportunities Chairman for the latest monthly Bulletin.

INDUSTRIAL ENGINEERING OPPORTUNITIES

Position number	Industry, location		Travel	Job classification number (See key)	Salary	Qualifications required		
					Range in $1,000	Adv. degree req.?	Years of exper.	Age range
								from to
85	Aircraft Eng.	NJ		10 or 50				
86	Public Utility	DC		13, 18, 37, 50, 52				
87	Linoleum Mfg.	Pa		42, 26, 11, 53, 81			0-3	
88	Air Force	O		13				
89	Foundry	Cal						
90	Education	Fla						
91	Syn. Fibers & Films	Pa, Va, W Va		10, 20, 42, 43, 72			0-5	
92	Paper Mill	Pa		11, 13, 42			2-3	
93	Foundry	Ill		11, 19, 30				
95	Airframe Mfg.	Midwest		92 13, 19, 11, 40			5	30 40
96	Navy	Md		40	7.5-8.6		3.5	
97	Railroad	Md		54, 50, 11	8.4			
98	Timber Mill	N West	X	91 30, 40				35
99	Process	NJ		92 30	12-15			35 45
100	Manufacturing	Ill		95	15 + B			37 42
101	Air Force	Ala		13	5.4		2	
102	Diversified Mfg.	NY		92 Mfg.	20-35			
103	Durable Goods	NY		11, 13, 21, 42	5.2-6.0			
104	Rug Mill	Pa		11, 13, 21, 42	6.0-7.0			
105	Electrical	Mass		92 or 37 or 11	6.5-11.0			
106	Sugar	ND, La, SC, Conn		13, 43			0	
107	Aircraft	Wash		13, 30				
108	Mgmt. Consult.	Overseas	X	10, 20, 60				35 40
109	Paper	NH			6.0-6.5			
110	Aircraft	Tex		11, 13, 19, 70	5.4-6.6			
111	Chemical	Ala			7.5			
112	Aircraft	Tex		11, 40, 70				
113	Chemicals	NJ		52				
114	Paper	Mo		11				
115	Foundry, Educ.	Pa						
116	Instruments	NY		71	8.0			
117	Electrical	Mass		50				
118	Mfg.	Pa		11, or 16 or 37			1-8	
119	Paper	Ga		10, 20, 30, 42				
120	Air Force	Ga		I.E.	7.0			
121	Navy	Cal		11, 13, 42, 43, 53	6.1-7.6		2-6	
122	Navy	Va		I.E.				
123	Printing	NY		19, 53			2-4	
124	Mineral Prod.	NJ		11, 53			0-3	
125	Chemical	Mich		13, 21, 43, 33			1-5	

AIIE OPPORTUNITIES SERVICE

Key to Job Classifications

No.	Job Classification
10	Motion and Time Study
11	Methods Improvement
12	Suggestion Systems
13	Work Measurement and Perf. Stds.
14	Stop-Watch Time Study
15	Std. Time Data Dev. & Applic.
16	Predeter. Elemental Time Stds.
18	Work Sampling
19	Estimating and Costing
20	Wage Payment
21	Incentive Plans
22	For Production Workers
23	For Non Prod. & Maint. Workers
24	For Supervisory Personnel
26	Job Evaluation
28	Wage Administration
30	Production Engineering
31	Production Control
32	Process Planning and Routing
33	Scheduling and Loading
34	Flow Process Charting
35	Inventory Control
36	Cost Anal. & Reduction
37	Statistical Quality Control
38	Budgetary Control, Standard Costs
39	Tool and Gage Design and Control
40	Plant Engineering
41	Plant Location & Expansion
42	Plant Layout
43	Material Handling
44	Machinery & Equipment
45	Specif., Select. & Eval.
46	Replacement
47	Automation
48	Plant Maintenance
49	Cap. Budget. Facil. Plan.
50	Operations Research
51	System & Simulation with "Models"
52	Mathematical Analysis
53	Engr. Economy Studies
54	Auto. Data Proc. with Computers
55	Market Research & Forecasting
60	Industrial Relations
61	Personnel Administration
62	Personnel Testing
63	Personnel Training
64	Industrial Psychology
65	Labor Relations
66	Safety Engineering
67	Suggestion Systems
70	Systems and Procedures
71	Admin. & Operating Procedures
72	Organization Charts and Manuals
73	Records Admin. & Form Control
80	Product Design
81	Packaging
90	Management and Supervision
91	Industrial Engineering Supr.
92	Chief I. E. or Equiv.
93	Plant Engineer
94	Production Supervisor
95	Plant Mgr., Fact. Mgr., Works Mgr.
96	General Manager

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